IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
BEFORE THE BOARD OF PATENT APPEALS AND INTERFERENCES

SUPPLEMENTAL APPEAL BRIEF

Inventors	:	Oehrke, *et al.*
Serial No.	:	09/021,466
Filing Date	:	February 10, 1998
Title	:	SURVIVABLE AND SCALABLE DATA SYSTEM AND METHOD FOR COMPUTER NETWORKS
Group/Art Unit	:	2153
Examiner	:	Dinh, Dung C.
Docket No.	:	1177

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

In accordance with the provisions of 37 C.F.R. §1.193(b)(2), Applicant submits this Supplemental Appeal Brief in response to the Office Action mailed on August 28, 2003.

I. REAL PARTY IN INTEREST

The real party in interest in the present appeal is the assignee, Sprint Communications Company, L.P. The assignment was recorded at Reel 8976, Frame 0965 of the U.S. Patent and Trademark Office records.

Certificate of Mailing Under 37 C.F.R. 1.8

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Date: January 28, 2004
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Printed Name: MERRY LONGSWORTH

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II. RELATED APPEALS AND INTERFERENCES

Applicant filed an Appeal Brief with the U.S. Patent and Trademark Office on February 20, 2003. An Office Action was mailed on August 28, 2003, in which the Examiner indicated that "Applicant's argument in the Appeal Brief filed 2/24/03 is persuasive and, therefore, finality is withdrawn." The Examiner also cited a new ground of rejection (as discussed below). This Supplemental Appeal Brief is filed in response to the outstanding Office Action, pursuant to 37 C.F.R. § 1.193(b)(2).

III. STATUS OF CLAIMS

Claims 79-115 are pending in the application. Claims 1-78 have been canceled. Claims 79-115 stand rejected, as follows: claims 79-80, 82-88, 91-95, 98-99, 102-104, 106 and 108-114 stand rejected under 35 U.S.C. § 102(e) as being anticipated by U.S. Patent No. 5,610,841 to *Tanaka, et al.*; claims 81, 89, 96, 100, 105, 107 and 115 stand rejected under 35 U.S.C. § 103(a) as being obvious over U.S. Patent No. 5,610,841 to *Tanaka, et al.*; and claims 90, 97 and 101 stand rejected under 35 U.S.C. § 103(a) as being obvious over U.S. Patent No. 5,610,841 to *Tanaka, et al.* in view of U.S. Patent No. 4,914,570 to *Peacock.* This Supplemental Appeal Brief is directed to claims 79-115.

IV. STATUS OF AMENDMENTS

Claims 79-115 have not been amended. These claims are reproduced in Appendix A attached hereto.

V. SUMMARY OF THE INVENTION

The present invention is directed to a system and method for providing network processing and stored data access that is configured to be fully scalable and/or fully survivable. Two different embodiments of the invention are shown in Figs. 1 and 2 of the application, attached hereto as Appendix B. As can be seen, at least one server (also referred to as an application processor) is provided that is operable to process user requests. The server is connected to a switch, which is in turn connected to at least one data storage device.

In one aspect of the invention, the system is fully "scalable" in the sense that additional servers can be added to the system as demand for a particular application increases, without adding additional data storage devices. Conversely, servers can be removed from the system without removing data storage devices. In a similar manner, additional data storage devices can be added to the system as storage requirements for a particular application increase, without adding additional servers. Conversely, data storage devices can be removed from the system without removing servers. Thus, the system is scalable to increase or decrease server capacity without changing the data storage capacity, and/or is scalable to increase or decrease data storage capacity without changing the server capacity.

In another aspect of the invention, the system includes at least two servers that apply substantially the same application(s) when processing user requests, and at least two data storage devices that contain substantially identical data. The system is fully "survivable" in the sense that, if any one of the servers fails, user requests can be processed by any of the other servers in the system that are operable. Likewise, if any one of the data storage devices fails, substantially identical data can be retrieved from any of the other data storage devices that are operable. Thus, the system is survivable and able to process user requests in the event of a failure of any one of the servers, and is survivable and able to retrieve data in the event of a failure of any one of the data storage devices.

Claims 79-85, 89-97, 102, 104-108, 110 and 112 are directed to the scalability aspect of the claimed invention. Claims 98-101 and 114-115 are directed to the survivability aspect of the claimed invention. Claims 86-88, 103, 109, 111 and 113 are directed to both the scalability and survivability aspects of the claimed invention.

VI. ISSUES

The issues on appeal are as follows:

A. Whether claims 79-80, 82-88, 91-95, 98-99, 102-104, 106 and 108-114 are unpatentable under 35 U.S.C. § 102(e) as being anticipated by U.S. Patent No. 5,610,841 to *Tanaka, et al.*

B. Whether claims 81, 89, 96, 100, 105, 107 and 115 are unpatentable under 35 U.S.C. § 103(a) as being obvious over U.S. Patent No. 5,610,841 to *Tanaka, et al.*

C. Whether claims 90, 97 and 101 are unpatentable under 35 U.S.C. § 103(a) as being obvious over U.S. Patent No. 5,610,841 to *Tanaka, et al.* in view of U.S. Patent No. 4,914,570 to *Peacock.*

VII. GROUPING OF THE CLAIMS

With respect to the rejection stated in Issue A, claims 79-80, 82-85, 91-95, 102, 104, 106, 108, 110 and 112 stand or fall together; claims 98-99 and 114 stand or fall together; and claims 86-88, 103, 109, 111 and 113 stand or fall together. As discussed in Section VIII.A.4 below, these three different groups of claims are separately patentable.

With respect to the rejection stated in Issue B, claims 81, 89, 96, 105 and 107 stand or fall together; and claims 100 and 115 stand or fall together. As discussed in Section VIII.B.3 below, these two different groups of claims are separately patentable.

With respect to the rejection stated in Issue C, claims 90 and 97 stand or fall together; and claim 101 stands or falls alone. As discussed in Section VIII.C.3 below, these two different groups of claims are separately patentable.

VIII. ARGUMENT

A. Applicant's Claims are not Anticipated by *Tanaka*

The Examiner rejected claims 79-80, 82-88, 91-95, 98-99, 102-104, 106 and 108-114 under 35 U.S.C. § 102(e) as being anticipated by U.S. Patent No. 5,610,841 to *Tanaka, et al.* ("*Tanaka*"), attached hereto as Appendix C. However, as discussed below, *Tanaka* does not disclose the survivability and/or scalability aspects of the claimed invention.

1. The *Tanaka* Disclosure

Tanaka discloses a video server for the storage and transmission of compressed video programs. As shown in Fig. 2, the video server includes a plurality of media segment file servers (MSFS) (1000-1005...), a system manager (SM) (2000), and a plurality of sequence control brokers (SCB) (3000-3002...), all of which transmit data to each other via an ATM switch (4000). *Tanaka*, col. 9, ll. 52-58. As shown in Fig. 1, each video program is divided into a plurality of media segment files (MSF). *Tanaka*, col. 9, ll. 40-51. Each MSF is stored separately on a MSFS located within the video server. *Tanaka*, col.9, l. 63 to col. 10, l. 11. For example, as shown in Fig. 3, program 1 is divided into 2000 MSF's, wherein MSF(1) is stored on MSFS (1000), MSF(2) is stored on MSFS (1001), MSF(3) is stored on MSFS (1002), and so on. *Id.*

In operation, a user at a subscriber terminal sends a request for a video program to the video server. *Tanaka*, col. 10, ll. 15-62. The request is received by one of the SCB's, which requests a sequential control file (SCF) for the requested video program from the SM (2000). *Id.* The SCF contains media signal file pointers that indicate the location of each of the MSF's for the requested video program in the array of MSFS's. *Id.* The SCF is then transmitted to the MSFS's, which, in turn, transmit the stored MSF's for the requested video program to the SCB. The SCB then sequentially aligns the MSF's for transmission of the video program to the subscriber terminal. *Id.*

2. *Tanaka* Does Not Disclose the Scalability Aspect of the Claimed Invention

Independent claims 79, 82, 91, 102, 104 and 106 (and dependent claims 80, 83-88, 92-95, 103 and 108-113), which are directed to the scalability aspect of the claimed invention,[1] each require that a server operates independently of a data storage device so as to permit the addition (or removal) of a server without the addition (or removal) of a data storage device (e.g., as demand for a particular application increases or decreases). *Tanaka* does not disclose or suggest this limitation.

The Examiner cites to two portions of the "Summary of the Invention" in *Tanaka* to support his contention that *Tanaka* discloses the claimed invention. However, as shown below, neither of these portions disclose a server that operates independently of a data storage device to permit the addition (or removal) of a server without the addition (or removal) of a data storage, as claimed by Applicant:

[1]/ Dependent claims 86-88, 103, 109, 111 and 113 are also directed to the survivability aspect of the claimed invention, discussed in Section VIII.A.3 below.

1. Tanaka, col. 4, ll. 22-30
The first cited paragraph discloses that when there are a plurality of requests for the same video program, each frame block server reads out the frame blocks (*e.g.*, MSF's) independently and sends the same to each subscriber terminal simultaneously. This allows multiple subscribers to access the same video program at the same time. The second cited paragraph discloses that because the ATM switch operates asynchronously, the number of subscribers and the kinds of video programs can easily be changed.

2. Tanaka, col. 7, ll. 1-7
The first cited paragraph discloses that a disk array may comprise K disk drives for storing the frame blocks (*e.g.*, MSF's), and the address of each frame block may be formatted for a readout command. The second cited paragraph discloses that the frame blocks (*e.g.*, MSF's) can be transferred between a plurality of ATM switches to extend the scale of the video server.

Significantly, the Examiner does not cite to any portion of *Tanaka* that even remotely discloses or suggests the claimed invention. Rather, the portions cited by the Examiner relate to the frame blocks (*e.g.*, MSF's) and the manner in which they can be read out through the ATM switch for transmission to a subscriber terminal.

Thus, independent claims 79, 82, 91, 102, 104 and 106 (and dependent claims 80, 83-88, 92-95 and 108-113) are not anticipated by *Tanaka* and should be allowed.

3. *Tanaka* Does Not Disclose the Survivability Aspect of the Claimed Invention

Independent claims 98 and 114 (and dependent claims 86-88, 99, 109, 103, 111 and 113), which are directed to the survivability aspect of the claimed invention,[2] each require first and second (or a plurality of) data storage devices that each store substantially the same data such that, in the event of a failure of any one of the data storage devices, the data is accessible from any other of the data storage devices that are operable. *Tanaka* does not disclose or suggest this

[2] Dependent claims 86-88, 103, 109, 111 and 113 are also directed to the scalability aspect of the claimed invention, discussed in Section VIII.A.2 above.

limitation. Rather, in *Tanaka*, each MSFS stores a different combination of MSF's such that no one MSFS stores substantially the same MSF's as any other MSFS.

For example, as shown in Fig. 3, MSFS (1000) stores MSF(1) and MSF(1001) of program 1, MSF(1) of program 2, and MSF(1) of program 3. By contrast, MSFS (1001) stores MSF(2) and MSF(1002) of program 1, MSF(2) of program 2, and MSF(2) of program 3. MSFS (1002) and MSFS (1999) (as well as the remaining MSFS's) also each store a unique combination of MSF's. As such, *Tanaka* teaches against the storage of substantially the same data in each of the data storage devices for protection against equipment failure, as claimed by Applicant.

Thus, independent claims 98 and 114 (and dependent claims 86-88, 99, 103, 109, 111, and 113) are not anticipated by *Tanaka* and should be allowed.

4. Different Groups of Claims are Separately Patentable

Claims 79-80, 82-85, 91-95,102, 104, 106, 108, 110 and 112 are directed to the scalability aspect of the claimed invention, and are not anticipated by *Tanaka* for the reasons discussed in Section VIII.A.2 above. Claims 98, 99 and 114 are directed to the survivability aspect of the claimed invention, and are not anticipated by *Tanaka* for the reasons discussed in Section VIII.A.3 above. Claims 86-88, 103, 109, 111 and 113 are directed to both the scalability and survivability aspects of the claimed invention, and are not anticipated by *Tanaka* for the reasons discussed in Sections VIII.A.2 and VIII.A.3 above.

B. Applicant's Claims are not Obvious Over *Tanaka*

The Examiner rejected claims 81, 89, 96, 100, 105, 107 and 115 under 35 U.S.C. § 103(a) as being obvious over *Tanaka* (described in Section VIII.A.1 above). A prima facie case of obviousness for rejecting these claims has not been established in that *Tanaka* does not disclose or suggest Applicant's claimed invention. The Patent and Trademark Office's burden of establishing a prima facie case of obviousness is not met unless "'the teachings from the prior art itself would appear to have suggested the claimed subject matter to a person of ordinary skill in the art.'" In re Bell, 26 U.S.P.Q. 2d 1529, 1531 (Fed. Cir. 1993)(quoting In re Rinehart, 189 U.S.P.Q. 143,147 (C.C.P.A. 1976)).

1. *Tanaka* Does Not Disclose or Suggest the Scalability Aspect of the Claimed Invention

Dependent claims 81, 89, 96, 105 and 107 are directed to the scalability aspect of the claimed invention. Claim 81 depends from independent claim 79; claim 89 depends from independent claim 82; claim 96 depends from independent claim 91; claim 105 depends from independent claim 104; and claim 107 depends from independent claim 106. Each of these independent claims (and thus each of dependent claims 81, 89, 96, 105 and 107) require that a server operates independently of a data storage device so as to permit the addition (or removal) of a server without the addition (or removal) of a data storage device. As discussed in Section VIII.A.2 above, the Examiner does not cite to any portion of *Tanaka* that even remotely discloses or suggests this limitation. Thus, the Examiner has failed to meet his burden of establishing a prima facie case of obviousness, and claims 81, 89, 96, 105 and 107 should be allowed.

2. *Tanaka* Does Not Disclose or Suggest the Survivability Aspect of the Claimed Invention

Dependent claims 100 and 115 are directed to the survivability aspect of the claimed invention. Claim 100 depends from independent claim 98; and claim 115 depends from independent claim 114. Each of these independent claims (and thus each of dependent claims 100 and 115) require first and second (or a plurality of) data storage devices that each store substantially the same data such that, in the event of a failure of any one of the data storage devices, the data is accessible from any other of the data storage devices that are operable. As discussed in Section VIII.A.3 above, *Tanaka* does not disclose or suggest this limitation. Rather, in *Tanaka*, each MSFS stores a different combination of MSF's such that no one MSFS stores substantially the same MSF's as any other MSFS. Thus, because the Examiner has failed to meet his burden of establishing a prima facie case of obviousness, claims 100 and 115 should be allowed.

3. Different Groups of Claims are Separately Patentable

Claims 81, 89, 96, 105 and 107 are directed to the scalability aspect of the claimed invention, and are not obvious over *Tanaka* for the reasons discussed in Section VIII.B.1 above. Claims 100 and 115 are directed to the survivability aspect of the claimed invention, and are not obvious over *Tanaka* for the reasons discussed in Section VIII.B.2 above.

C. Applicant's Claims are not Obvious Over *Tanaka* in View of *Peacock*

The Examiner rejected claims 90, 97 and 101 under 35 U.S.C. § 103(a) as being obvious over *Tanaka* (described in Section VIII.A.1 above) in view of U.S. Patent No. 4,914,570 to *Peacock* ("*Peacock*"), attached hereto as Appendix D. *Peacock* discloses a multiple processor computer system. A prima facie case of obviousness for rejecting these claims has not been established in that *Tanaka* and *Peacock* do not alone or in combination disclose or suggest Applicant's claimed invention. Furthermore, these cited references are not properly combinable. The Patent and Trademark Office's burden of establishing a prima facie case of obviousness is not met unless "'the teachings from the prior art itself would appear to have suggested the claimed subject matter to a person of ordinary skill in the art.'" In re Bell, 26 U.S.P.Q. 2d 1529, 1531 (Fed. Cir. 1993)(quoting In re Rinehart, 189 U.S.P.Q. 143,147 (C.C.P.A. 1976)).

1. *Tanaka* and *Peacock* Do Not Disclose or Suggest the Scalability Aspect of the Claimed Invention and are not Properly Combinable

Dependent claims 90 and 97 are directed to the scalability aspect of the claimed invention. Claim 90 depends from independent claim 82; and claim 97 depends from independent claim 91. Each of these independent claims (and thus each of dependent claims 90 and 97) require that a server operates independently of a data storage device so as to permit the addition (or removal) of a server without the addition (or removal) of a data storage device. Neither *Tanaka* nor *Peacock* disclose or suggest this limitation. As discussed in Section VIII.A.2 above, the Examiner does not cite to any portion of *Tanaka* that even remotely discloses or suggests this limitation. *Peacock* merely discloses a multiple processor computer system in which each of the processors has its own associated memory, but also has access to the memories of the other processors. Thus, Applicant's claimed invention is clearly distinguishable from *Tanaka* and *Peacock.*

Furthermore, "[b]efore the PTO may combine the disclosures of two or more prior art references in order to establish prima facie obviousness, there must be some suggestion for doing so, found either in the references themselves or in the knowledge generally available to one of ordinary skill in the art." In re Jones, 21 U.S.P.Q. 2d 1941, 1943-44 (Fed. Cir. 1992). If there is no technological motivation for modifying a reference, then the reference should not be part of a §103 rejection. In the present case, there is no motivation to combine *Tanaka* and *Peacock. Tanaka* discloses the various components of a video server. By contrast, *Peacock* discloses the inner-workings of a multiple processor computer system. Nothing in either reference suggests that any one of the various components of *Tanaka* could be modified in accordance with the teachings of *Peacock.*

Still further, even if the references were somehow combined, the combination of *Tanaka* and *Peacock* does not disclose or suggest Applicant's claimed invention. Specifically, the combination does not disclose or suggest a server that operates independently of a data storage device so as to permit the addition (or removal) of a server without the addition (or removal) of a data storage device, as claimed by Applicant.

Thus, the Examiner has failed to meet his burden of establishing a prima facie case of obviousness, and claims 90 and 97 should be allowed.

2. *Tanaka* and *Peacock* Do Not Disclose or Suggest the Survivability Aspect of the Claimed Invention and are not Properly Combinable

Dependent claim 101 is directed to the survivability aspect of the claimed invention. Claim 101 depends from independent claim 98, which requires a plurality of data storage devices that each store substantially the same data such that, in the event of a failure of any one of the data storage devices, the data is accessible from any other of the data storage devices that are operable. Neither *Tanaka* nor *Peacock* disclose or suggest this limitation. As discussed in Section VIII.A.3 above, in *Tanaka*, each MSFS stores a different combination of MSF's such that no one MSFS stores substantially the same MSF's as any other MSFS. *Peacock* merely discloses a multiple processor computer system in which each of the processors has its own associated memory. Thus, Applicant's claimed invention is clearly distinguishable from *Tanaka* and *Peacock.*

Furthermore, "[b]efore the PTO may combine the disclosures of two or more prior art references in order to establish prima facie obviousness, there must be some suggestion for doing so, found either in the references themselves or in the knowledge generally available to one of ordinary skill in the art." In re Jones, 21 U.S.P.Q. 2d 1941, 1943-44 (Fed. Cir. 1992). If there is no technological motivation for modifying a reference, then the reference should not be part of a §103 rejection. In the present case, there is no motivation to combine *Tanaka* and *Peacock. Tanaka* discloses the various components of a video server. By contrast, *Peacock* discloses the inner-workings of a multiple processor computer system. Nothing in either reference suggests that any one of the various components of *Tanaka* could be modified in accordance with the teachings of *Peacock.*

Still further, even if the references were somehow combined, the combination of *Tanaka* and *Peacock* does not disclose or suggest Applicant's claimed invention. Specifically, the combination does not disclose or suggest a plurality of data storage devices that <u>each</u> store <u>substantially the same data</u> such that, in the event of a failure of <u>any one</u> of the data storage devices, the data is accessible from <u>any other</u> of the data storage devices that are operable, as claimed by Applicant.

Thus, the Examiner has failed to meet his burden of establishing a <u>prima</u> <u>facie</u> case of obviousness, and claim 101 should be allowed.

3. Different Groups of Claims are Separately Patentable

Claims 90 and 97 are directed to the scalability aspect of the claimed invention, and are not obvious over *Tanaka* in view of *Peacock* for the reasons discussed in Section VIII.C.1 above. Claim 101 is directed to the survivability aspect of the claimed invention, and is not obvious over *Tanaka* in view of *Peacock* for the reasons discussed in Section VIII.C.2 above.

IX. APPENDICES

Attached hereto are the following Appendices:

Appendix A – Claims on Appeal

Appendix B – Figs. 1 and 2 of the Application

Appendix C – U.S. Patent No. 5,699,503 to *Tanaka, et al.*

Appendix D – U.S. Patent No. 4,914,570 to *Peacock*

X. SUMMARY

For the foregoing reasons, Applicant respectfully submits that claims 79-115 are patentable over the cited references and should be allowed. Accordingly, Applicant respectfully requests that the Board reverse the Examiner's rejections of claims 79-115, and allow claims 79-115.

Respectfully submitted,

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APPENDIX A

Claims on Appeal

The text of the claims on appeal are as follows:

79. A scalable system for providing network processing and stored data access, the system comprising:

(a) a server operative to process user requests;

(b) a switch operatively connected to the server;

(c) a data storage device operatively connected to the switch; and

(d) wherein the server operates independently of the data storage device and is connected to the data storage device via the switch in a manner to permit the inclusion of an additional server to process other user requests without the inclusion of an additional data storage device.

8 0. The system of Claim 79 wherein the server operates independently of the data storage device and is connected to the data storage device via the switch in a manner to permit the inclusion of an additional data storage device without the inclusion of an additional server.

81. The system of Claim 79 wherein the server applies an application to the user requests, the application selected from the group consisting of: a mail application, a news application, a directory application, a content application, a groupware application, and an internet protocol (IP) service.

82. A scalable system for providing network processing and stored data access, the system comprising:

(a) at least first and second servers operative to process at least first and second user requests, respectively;

(b) a switch operatively connected to each of the servers;

(c) a plurality of data storage devices operatively connected to the switch; and

(d) wherein the servers operate independently of the data storage devices and are connected to the data storage devices via the switch in a manner to permit the inclusion of an additional server to process at least an additional user request without the inclusion of an additional data storage device.

83. The system of Claim 82 wherein the servers operate independently of the data storage devices and are connected to the data storage devices via the switch in a manner to permit the inclusion of an additional data storage device without the inclusion of an additional server.

84. The system of Claim 83 wherein the servers operate independently of the data storage devices and are connected to the data storage devices via the switch in a manner to permit the removal of any one of the plurality of data storage devices without the removal of any of the servers.

85. The system of Claim 82 wherein the servers operate independently of the data storage devices and are connected to the data storage devices via the switch in a manner to permit the removal of any one of the servers without the removal of any of the data storage devices.

86. The system of Claim 82 wherein each of the first and second servers applies an application, the application applied by the first server being substantially the same as the application applied by the second server such that, in the event of a failure of either of the first and second servers, any subsequent user requests will be processed by any other of the servers that are operable.

87. The system of Claim 82 wherein each of the plurality of data storage devices stores data, the data stored by each of the plurality of data storage devices being substantially the same such that, in the event of a failure of any one of the plurality of data storage devices, the data is accessible from any other of the plurality of data storage devices that are operable.

88. The system of Claim 82 wherein each of the first and second servers applies an application, the application applied by the first server being substantially the same as the application applied by the second server such that, in the event of a failure of either of the first and second servers, any subsequent user requests will be processed by any other of the servers that are operable, and wherein each of the plurality of data storage devices stores data, the data stored by each of the plurality of data storage devices being substantially the same such that, in

the event of a failure of any one of the plurality of data storage devices, the data is accessible from any other of the plurality of data storage devices that are operable.

89. The system of Claim 82 wherein each of the at least first and second servers applies an application selected from the group consisting of: a mail application, a news application, a directory application, a content application, a groupware application, and an internet protocol (IP) service.

90. The system of Claim 82 further comprising a load balancer operatively connected to each of the at least first and second servers, the load balancer operative to route an additional user request to the one of the at least first and second servers with the least load.

91. A scalable system for providing network processing and stored data access, the system comprising:

(a) at least first and second sets of servers, each of the sets of servers comprising at least first and second servers operative to process at least first and second user requests, respectively, and wherein each of the sets of servers applies a separate application;

(b) a switch operatively connected to each of the servers within each of the sets of servers;

(c) a plurality of data storage devices operatively connected to the switch; and

(d) wherein the sets of servers operate independently of the data storage devices and are connected to the data storage devices via the switch in a manner to permit the inclusion of an additional server to any of the sets of servers to process at least an additional user request without the inclusion of an additional data storage device.

92. The system of Claim 91 wherein the sets of servers operate independently of the data storage devices and are connected to the data storage devices via the switch in a manner to permit the inclusion of an additional data storage device without the inclusion of an additional server to any of the sets of servers.

93. The system of Claim 92 wherein the sets of servers operate independently of the data storage devices and are connected to the data storage devices via the switch in a manner to permit the removal of any one of the plurality of data storage devices without the removal of any of the servers from any of the sets of servers.

94. The system of Claim 93 wherein the data stored by any one of the plurality of data storage devices is associated with an application applied by any one of the sets of servers.

95. The system of Claim 91 wherein the sets of servers operate independently of the data storage devices and are connected to the data storage devices via the switch in a manner to permit the removal of any one of the servers from any one of the sets of servers without the removal of any of the plurality of data storage devices.

96. The system of Claim 91 wherein each of the at least first and second servers of any one of the sets of servers applies an application selected from the group consisting of: a mail application, a news application, a directory application, a content application, a groupware application, and an internet protocol (IP) service.

97. The system of Claim 91 wherein each of the at least first and second servers of any one of the sets of servers applies an application, and wherein the system further comprises a load balancer operatively connected to each of the at least first and second servers of each of the sets of servers, the load balancer operative to route user requests to the one of the at least first and second servers of the sets of servers with the least load for a particular application.

98. A survivable system for providing network processing and stored data access, the system comprising:

(a) at least first and second servers operative to process at least first and second user requests, respectively,

(b) a switch operatively connected to each of the servers;

(c) a plurality of data storage devices operatively connected to the switch;

(d) wherein each of the first and second servers applies an application, the application applied by the first server being substantially the same as the application applied by the second server such that, in the event of a failure of either of the first and second servers, any subsequent user requests will be processed by any other of the servers that are operable; and

(e) wherein each of the plurality of data storage devices stores data, the data stored by each of the plurality of data storage devices being substantially the same such that, in the event of a failure of any one of the plurality of data storage devices, the data is accessible from any other of the plurality of data storage devices that are operable.

99. The system of Claim 98 wherein the data stored by any one of the plurality of data storage devices is associated with an application applied by any one of the first and second servers.

100. The system of Claim 98 wherein each of the at least first and second servers applies an application selected from the group consisting of: a mail application, a news application, a directory application, a content application, a groupware application, and an internet protocol (IP) service.

101. The system of Claim 98 further comprising a load balancer operatively connected to each of the at least first and second servers, the load balancer operative to route user requests to the one of the at least first and second servers corresponding to the server with the least load.

102. A scalable system for providing network processing and stored data access, the system comprising:

(a) at least first and second servers operative to process at least first and second user requests, respectively;

(b) a switch operatively connected to each of the servers;

(c) a plurality of data storage devices operatively connected to the switch;

(d) a load balancer operatively connected to each of the at least first and second servers, the load balancer operative to route user requests to the one of the at least first and second servers with the least load; and

(e) wherein the servers operate independently of the data storage devices and are connected to the data storage devices via the switch in a manner to permit the inclusion of an additional server to process at least an additional user request without the inclusion of an additional data storage device, to permit the inclusion of an additional data storage device without the inclusion of an additional server, to permit the removal of any one of the servers without the removal of any of the data storage devices, and to permit the removal of any one of the data storage devices without the removal of any of the servers.

103. The system of Claim 102 wherein each of the first and second servers applies an application, the application applied by the first server being substantially the same as the application applied by the second server such that, in the event of a failure of either of the first and second servers, any subsequent user requests will be processed by any other of the servers that are operable, and wherein each of the plurality of data storage devices stores data, the data stored by each of the plurality of data storage devices being substantially the same such that, in the event of a failure of any one of the plurality of data storage devices, the data is accessible from any other of the plurality of data storage devices that are operable.

104. A method for providing network processing and stored data access, the method comprising the steps of:

(a) providing a server operative to apply an application;

(b) receiving a user request on the server;

(c) applying the application to the user request to generate a query;

(d) providing a data storage device configured to store data;

(e) switching the query to the data storage device;

(f) routing requested data from the data storage device to the server in response to the query; and

(g) providing an additional server without providing an additional data storage device, or alternatively, providing an additional data storage device without providing an additional server.

105. The method of Claim 104 wherein the application is selected from the group consisting of: a mail application, a news application, a directory application, a content application, a groupware application, and an internet protocol (IP) service.

106. A method for providing network processing and stored data access, the method comprising the steps of:

(a) providing at least first and second servers operative to apply first and second applications, respectively;

(b) receiving first and second user requests on the first and second servers, respectively;

(c) applying the first and second applications to the first and second user requests, respectively, to generate first and second queries, respectively;

(d) providing at least first and second data storage devices configured to store first and second data, respectively;

(e) switching the first and second queries to the first and second data storage devices, respectively;

(f) routing first requested data from the first data storage device to the first server in response to the first query, and routing second requested data from the second data storage device to the second server in response to the second query; and

(g) providing an additional server without providing an additional data storage device, or alternatively, providing an additional data storage device without providing an additional server.

107. The method of Claim 106 wherein each of the first and second applications is selected from the group consisting of: a mail application, a news application, a directory application, a content application, a groupware application, and an internet protocol (IP) service.

108. The method of Claim 106 wherein the first application is substantially the same as the second application.

109. The method of Claim 108 further comprising the step of:

(h) in the event of a failure of either of the first and second servers, processing any subsequent user requests on any other of the servers that are operable.

110. The method of Claim 106 wherein the first data is substantially the same as the second data.

111. The method of Claim 110 further comprising the step of:

(h) in the event of a failure of either of the first and second data storage devices, providing any subsequent requested data from any other of the data storage devices that are operable.

112. The method of Claim 106 wherein the first application is substantially the same as the second application, and wherein the first data is substantially the same as the second data.

113. The method of Claim 112 further comprising the steps of:

(h) in the event of a failure of either of the first and second servers, processing subsequent requests on any other of the servers that are operable; and

(i) in the event of a failure of either of the first and second data storage devices, providing any subsequent requested data from any other of the data storage devices that are operable.

114. A method for providing network processing and stored data access, the method comprising the steps of:

(a) providing at least first and second servers operative to apply first and second applications, respectively, the first application being substantially the same as the second application;

(b) receiving first and second user requests on the first and second servers, respectively;

(c) applying the first and second applications to the first and second user requests, respectively, to generate first and second queries, respectively;

(d) providing at least first and second data storage devices configured to store first and second data, respectively, the first data being substantially the same as the second data;

(e) switching the first and second queries to the first and second data storage devices, respectively;

(f) routing first requested data from the first data storage device to the first server in response to the first query, and routing second requested data from the second data storage device to the second server in response to the second query;

(g) in the event of a failure of either of the first and second servers, processing any subsequent requests on any other of the servers that are operable; and

(h) in the event of a failure of either of the first and second data storage devices, providing any subsequent requested data from any other of the data storage devices that are operable.

115. The method of Claim 114 wherein each of the first and second applications is selected from the group consisting of: a mail application, a news application, a directory application, a content application, a groupware application, and an internet protocol (IP) service.

B

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APPENDIX B

Figs. 1 and 2 of the Application

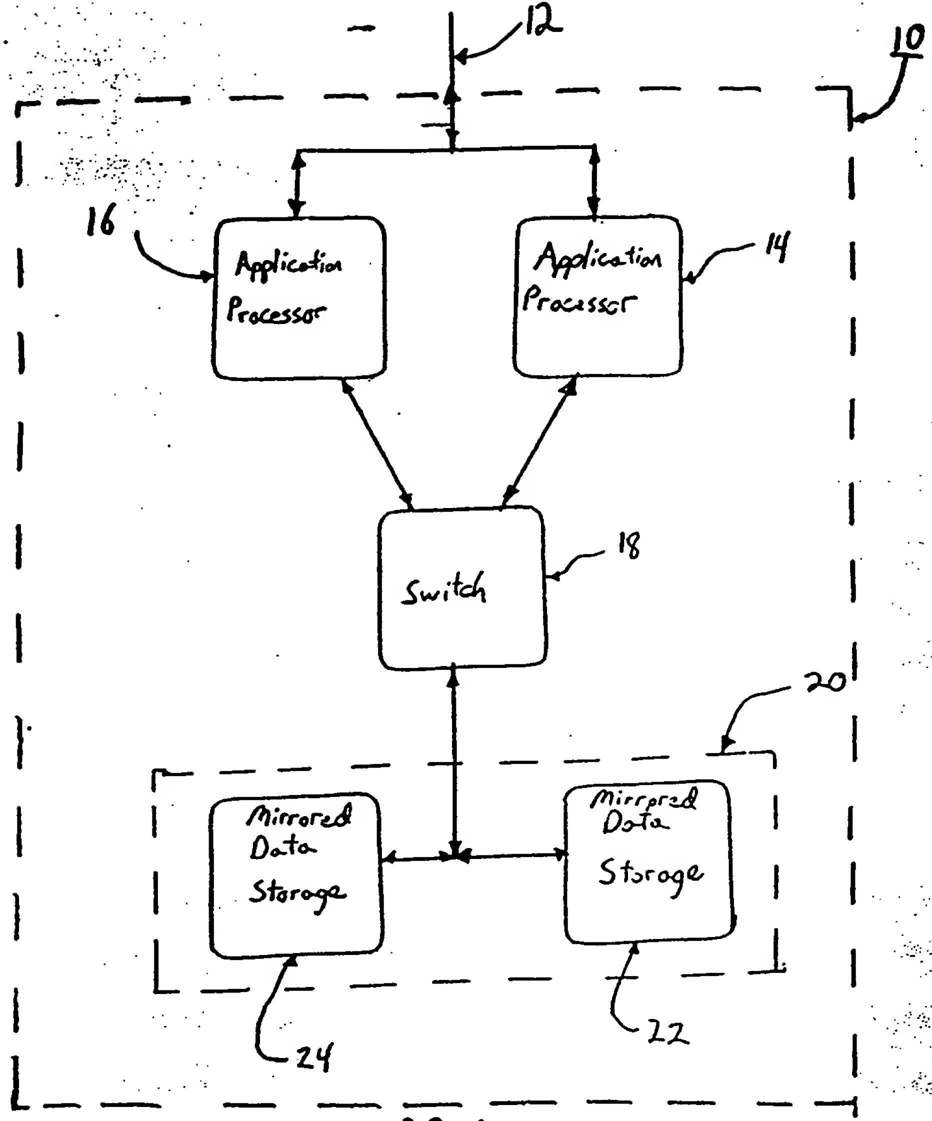
12
10
16
Application Processor
Application Processor
14
Switch
18
20
Mirrored Data Storage
Mirrored Data Storage
24
22

FIG. 1

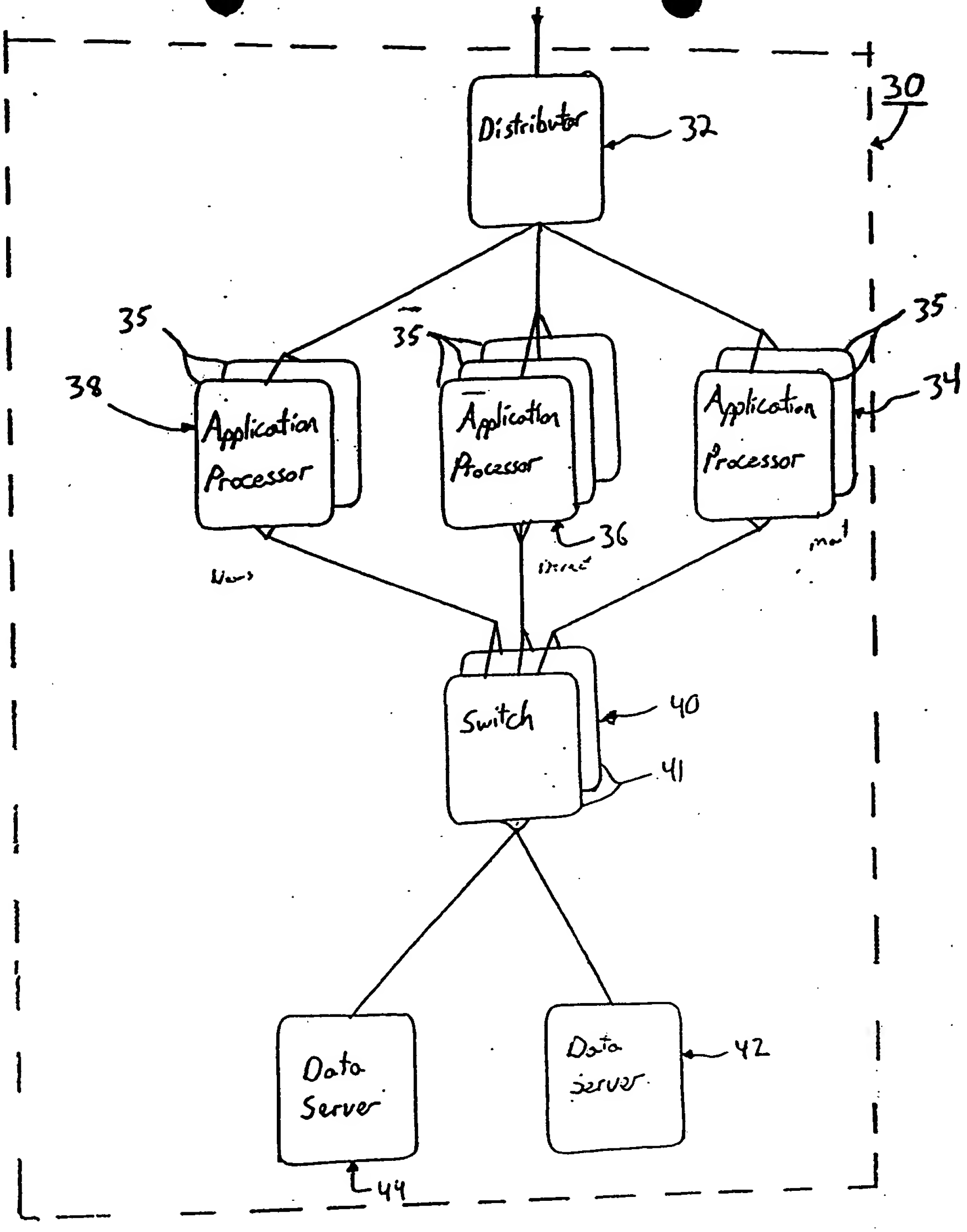
30
Distributor
32
35
35
35
38
Application Processor
Application Processor
Application Processor
34
36
News
Direct
mail
Switch
40
41
Data Server
Data Server
42
44

FIG. 2

C

APPENDIX C

U.S. Patent No. 5,60,841 to Tanaka, et al.

US005610841A

United States Patent [19]

Tanaka et al.

[11] **Patent Number: 5,610,841**

[45] **Date of Patent: Mar. 11, 1997**

[54] **VIDEO SERVER**

[75] Inventors: **Tsutomu Tanaka**, Nishinomiya; **Shinzo Doi**; **Hiroshi Yokota**, both of Osaka; **Chishio Ueno**, Ikoma; **Yukiko Ito**, Osaka, all of Japan

[73] Assignee: **Matsushita Electric Industrial Co., Ltd.**, Osaka, Japan

[21] Appl. No.: **316,514**

[22] Filed: **Sep. 30, 1994**

[30] **Foreign Application Priority Data**

Sep. 30, 1993	[JP]	Japan	5-269995
Jan. 20, 1994	[JP]	Japan	6-004472
Feb. 10, 1994	[JP]	Japan	6-016848
Apr. 4, 1994	[JP]	Japan	6-066063
Apr. 12, 1994	[JP]	Japan	6-073595
Apr. 27, 1994	[JP]	Japan	6-089585
Aug. 8, 1994	[JP]	Japan	6-185955

[51] **Int. Cl.^{6}** **H04N 9/79**

[52] **U.S. Cl.** .... **364/514 R**; 348/12

[58] **Field of Search** .... 364/514 C, 514 R; 348/12, 13, 6, 7; 370/94.2, 94.1; 395/600

[56] **References Cited**

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5,208,665	5/1993	McCalley et al.	348/12
5,287,530	2/1994	Davis et al. .	

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Nikkei Communications, p. 41, Feb. 15, 1993.
Nikkei Communications, p. 47, Feb. 15, 1993.

Primary Examiner—Emanual T. Voeltz
Assistant Examiner—Thomas Peeso
Attorney, Agent, or Firm—Price, Gess & Ubell

[57] **ABSTRACT**

A video server in which each media segment file sever (MSFS) stores media segment files (MSFs) forming video data, and sequence control brokers (SCBs) installed between the video server and subscribers terminals receive video requests from the subscriber terminals, and read out the requested MSFs from the MSFSs. The readout MSFs are exchanged by an ATM switch to be transmitted to the SCBs respectively, which outputs the MSFs at predetermined intervals to the request-sender subscriber terminals.

86 Claims, 63 Drawing Sheets

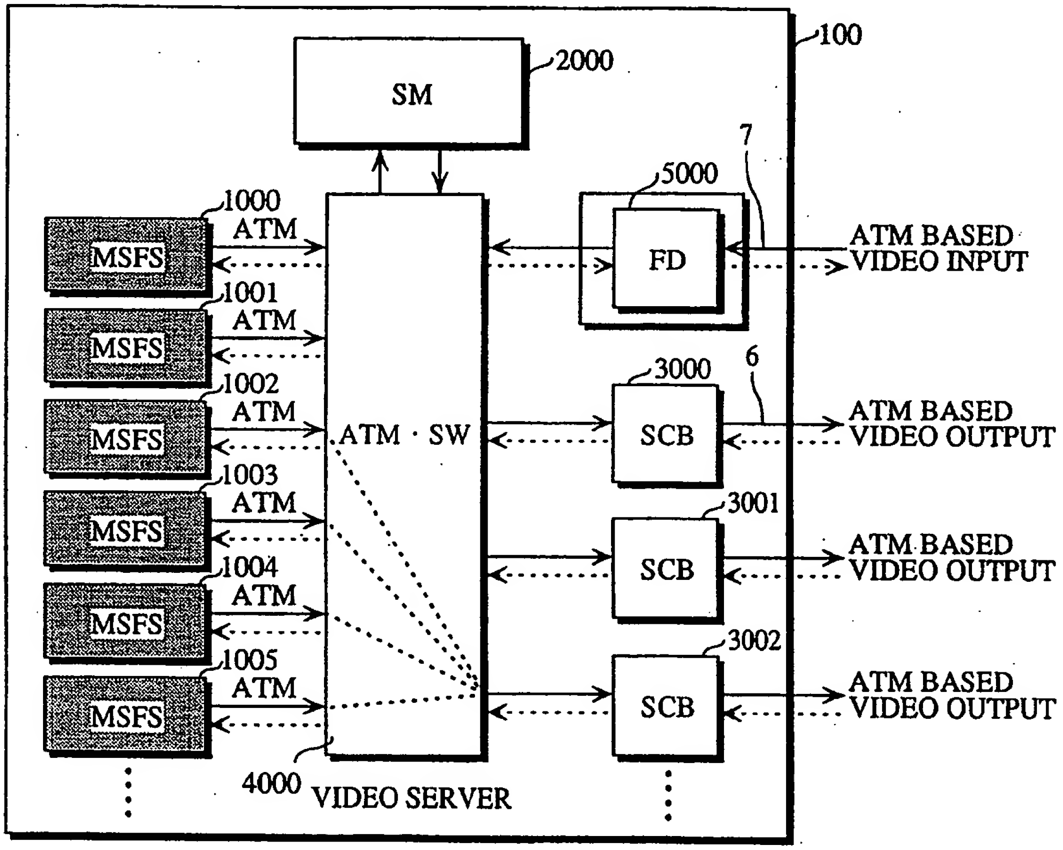


FIG. 1

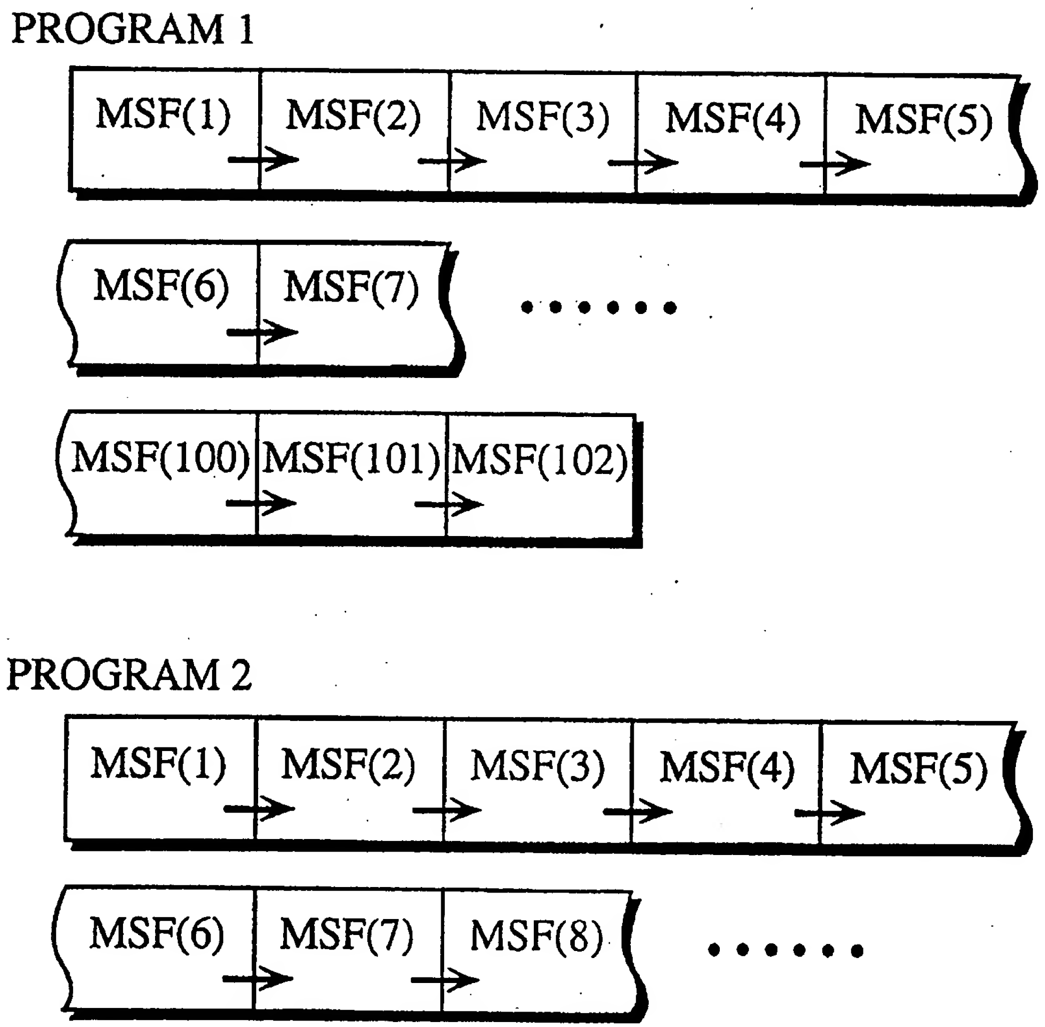

PROGRAM 1
MSF(1)
MSF(2)
MSF(3)
MSF(4)
MSF(5)
MSF(6)
MSF(7)
MSF(100)
MSF(101)
MSF(102)
PROGRAM 2
MSF(1)
MSF(2)
MSF(3)
MSF(4)
MSF(5)
MSF(6)
MSF(7)
MSF(8)

FIG. 2

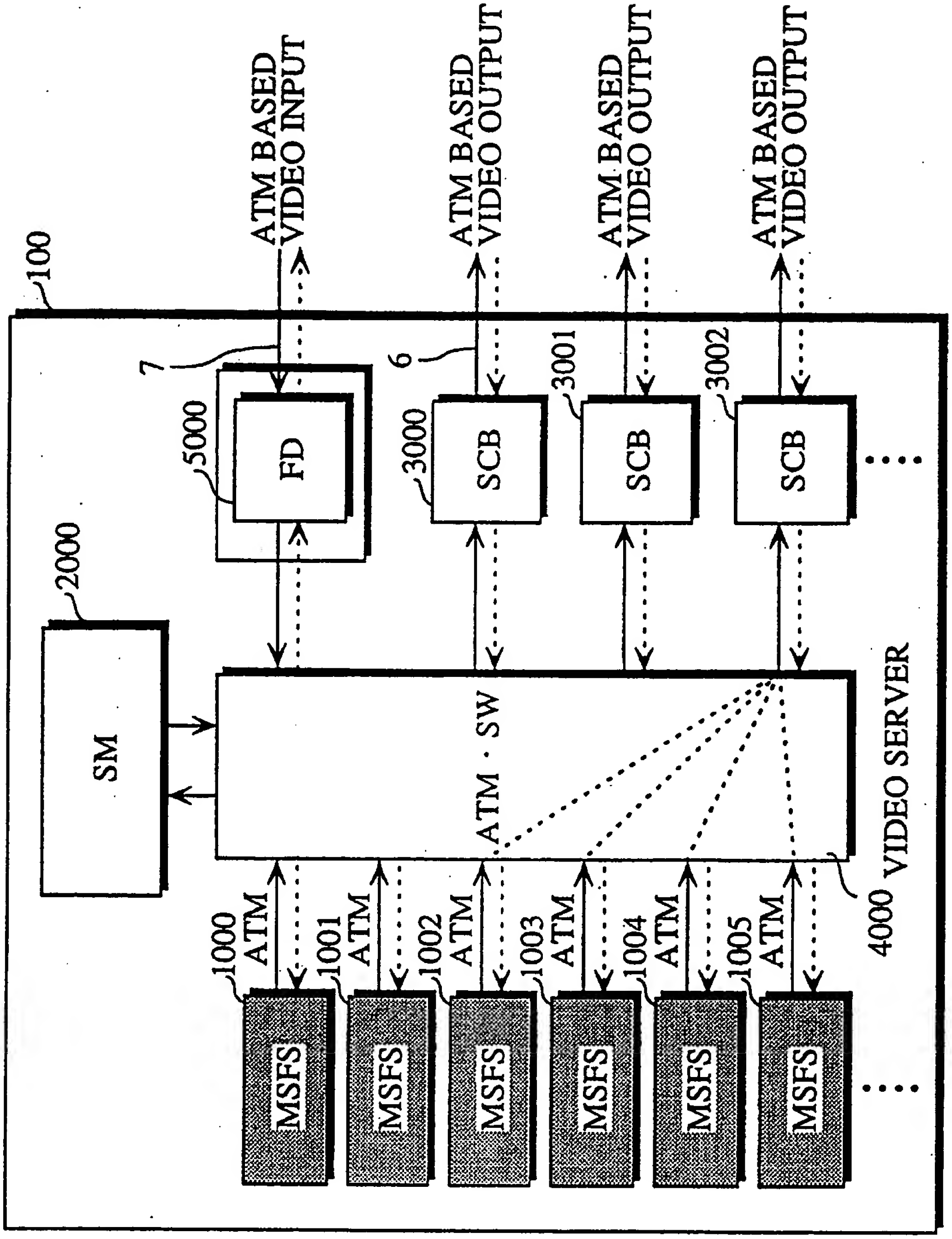

100
ATM BASED VIDEO INPUT
ATM BASED VIDEO OUTPUT
ATM BASED VIDEO OUTPUT
ATM BASED VIDEO OUTPUT
7
6
3001
3002
5000
FD
3000
SCB
SCB
SCB
....
2000
SM
ATM · SW
VIDEO SERVER
4000
1000
ATM
1001
ATM
1002
ATM
1003
ATM
1004
ATM
1005
ATM
MSFS
MSFS
MSFS
MSFS
MSFS
MSFS
....

FIG. 3

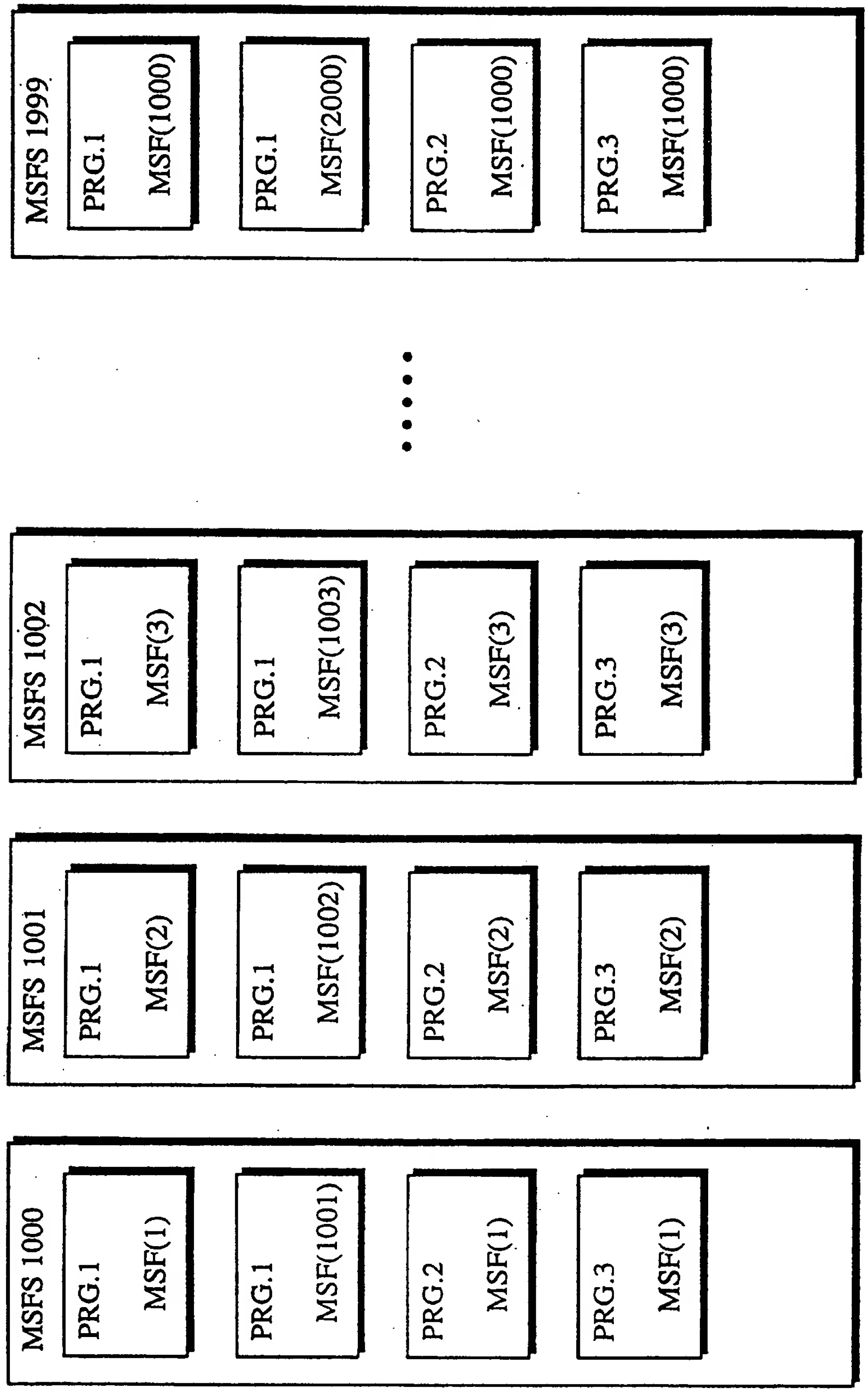
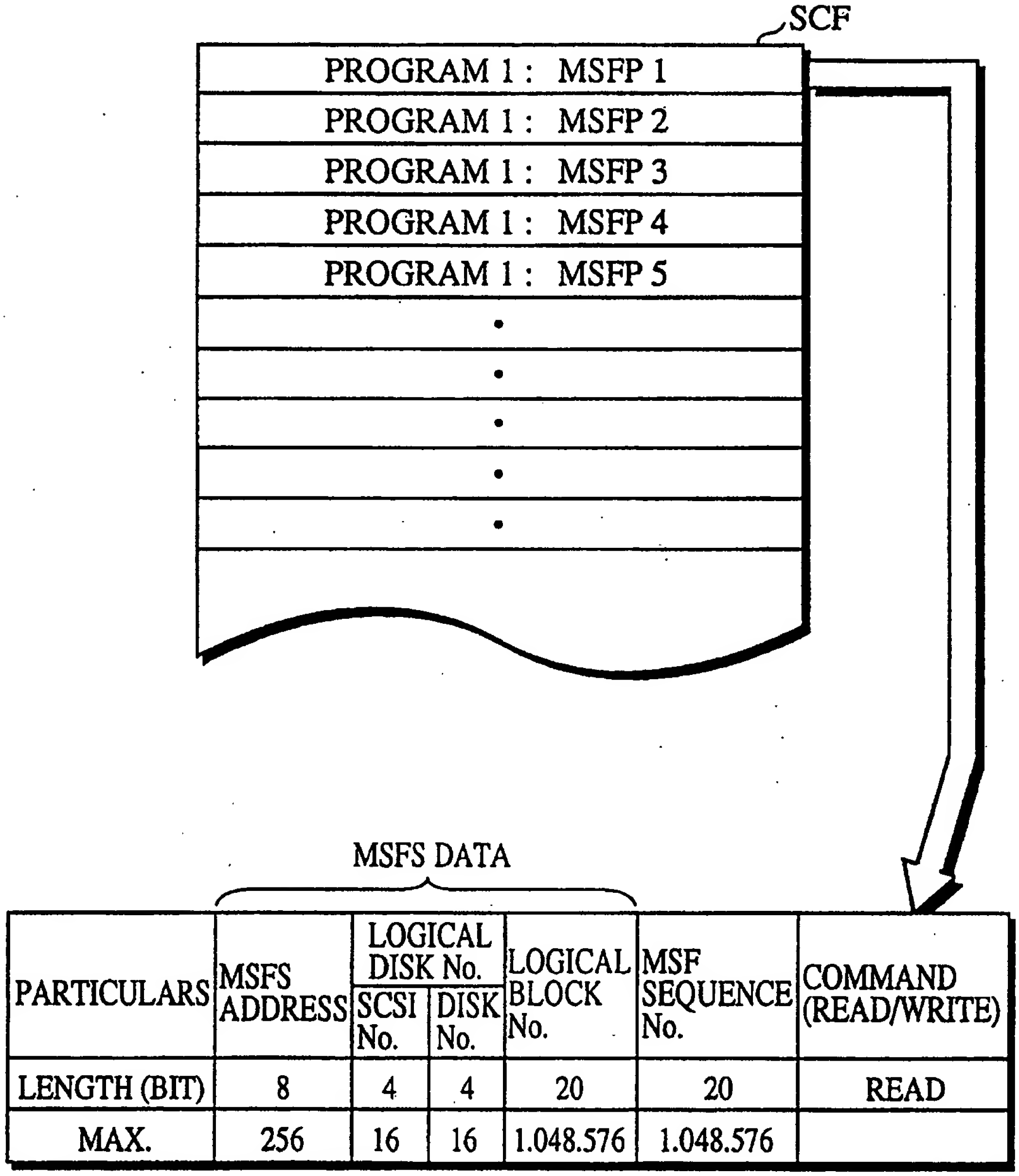
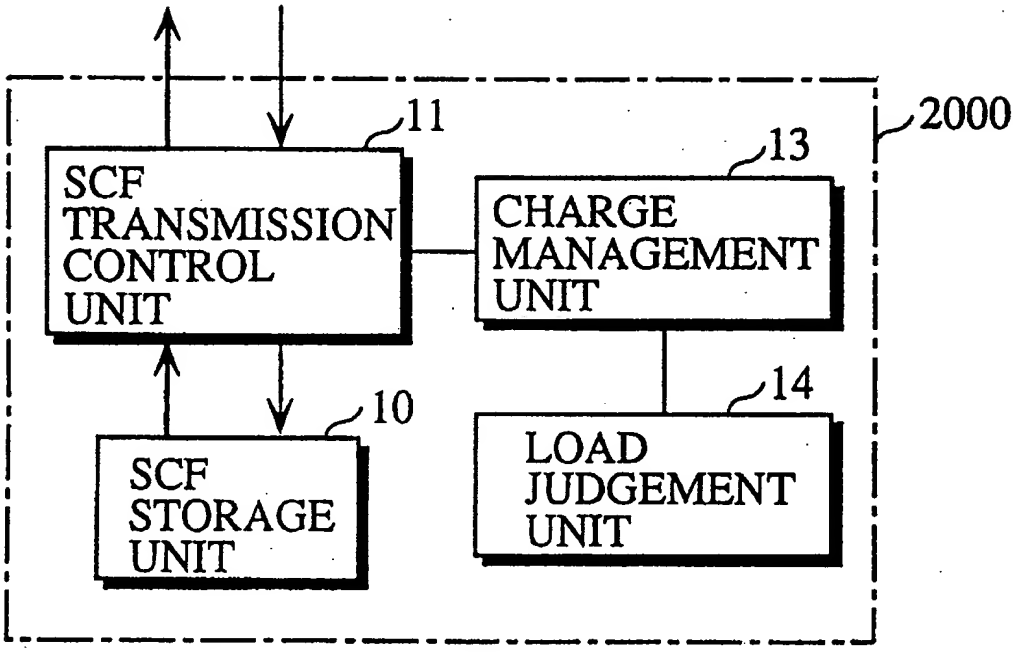

MSFS 1000
PRG.1 MSF(1)
PRG.1 MSF(1001)
PRG.2 MSF(1)
PRG.3 MSF(1)
MSFS 1001
PRG.1 MSF(2)
PRG.1 MSF(1002)
PRG.2 MSF(2)
PRG.3 MSF(2)
MSFS 1002
PRG.1 MSF(3)
PRG.1 MSF(1003)
PRG.2 MSF(3)
PRG.3 MSF(3)
MSFS 1999
PRG.1 MSF(1000)
PRG.1 MSF(2000)
PRG.2 MSF(1000)
PRG.3 MSF(1000)

FIG. 4



PARTICULARS	MSFS ADDRESS	LOGICAL DISK No.		LOGICAL BLOCK No.	MSF SEQUENCE No.	COMMAND (READ/WRITE)
		SCSI No.	DISK No.			
LENGTH (BIT)	8	4	4	20	20	READ
MAX.	256	16	16	1.048.576	1.048.576	

FIG. 5


2000
11
SCF TRANSMISSION CONTROL UNIT
13
CHARGE MANAGEMENT UNIT
10
SCF STORAGE UNIT
14
LOAD JUDGEMENT UNIT

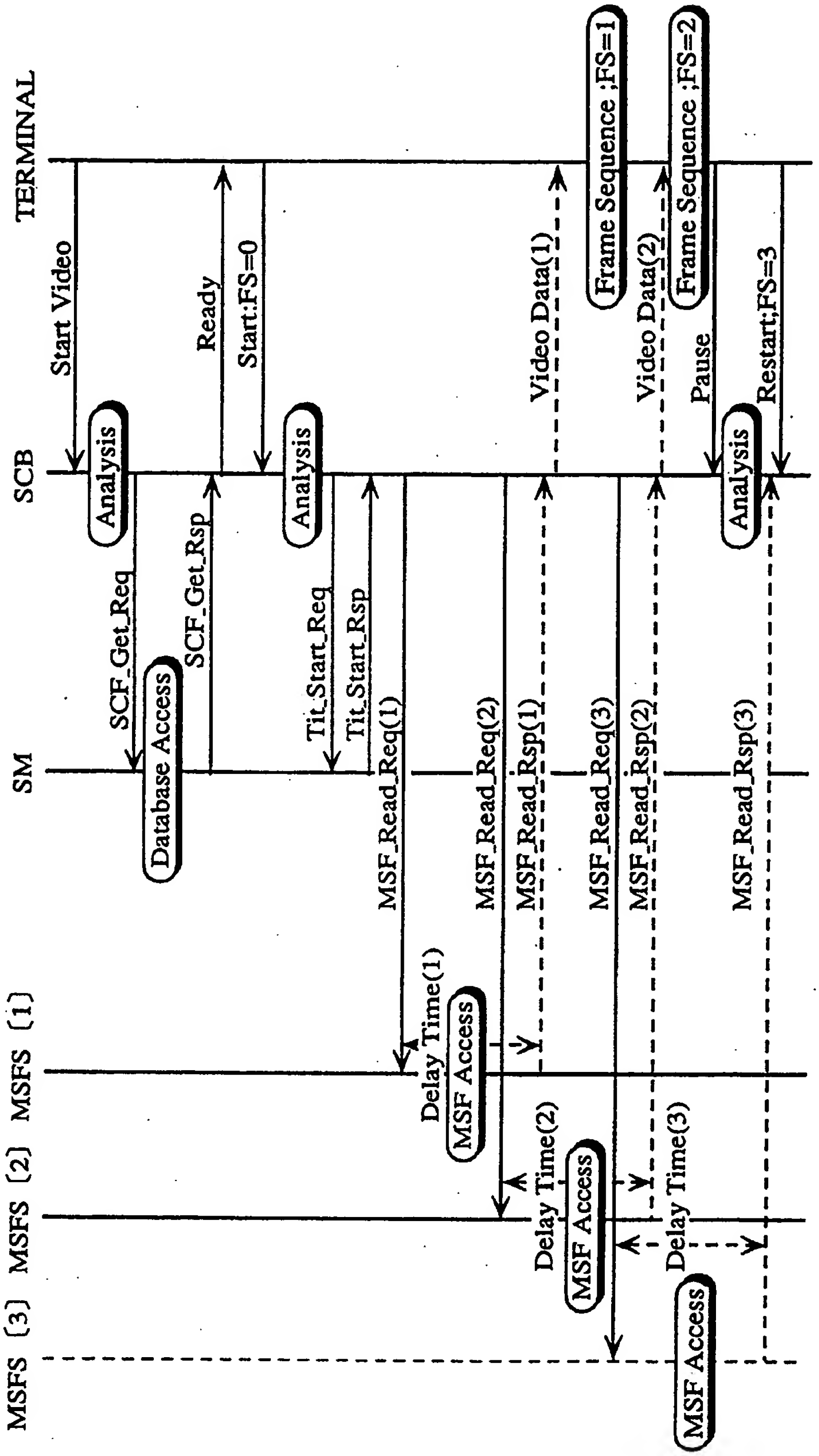

TERMINAL
SCB
SM
MSFS (1)
MSFS (2)
MSFS (3)
Start Video
Analysis
SCF_Get_Req
Database Access
SCF_Get_Rsp
Ready
Start:FS=0
Analysis
Tit_Start_Req
Tit_Start_Rsp
MSF_Read_Req(1)
Delay Time(1)
MSF Access
MSF_Read_Req(2)
MSF_Read_Rsp(1)
Video Data(1)
Frame Sequence ;FS=1
Delay Time(2)
MSF Access
MSF_Read_Req(3)
MSF_Read_Rsp(2)
Video Data(2)
Frame Sequence ;FS=2
Delay Time(3)
MSF Access
Pause
Analysis
Restart;FS=3
MSF_Read_Rsp(3)

FIG. 6

FIG. 7

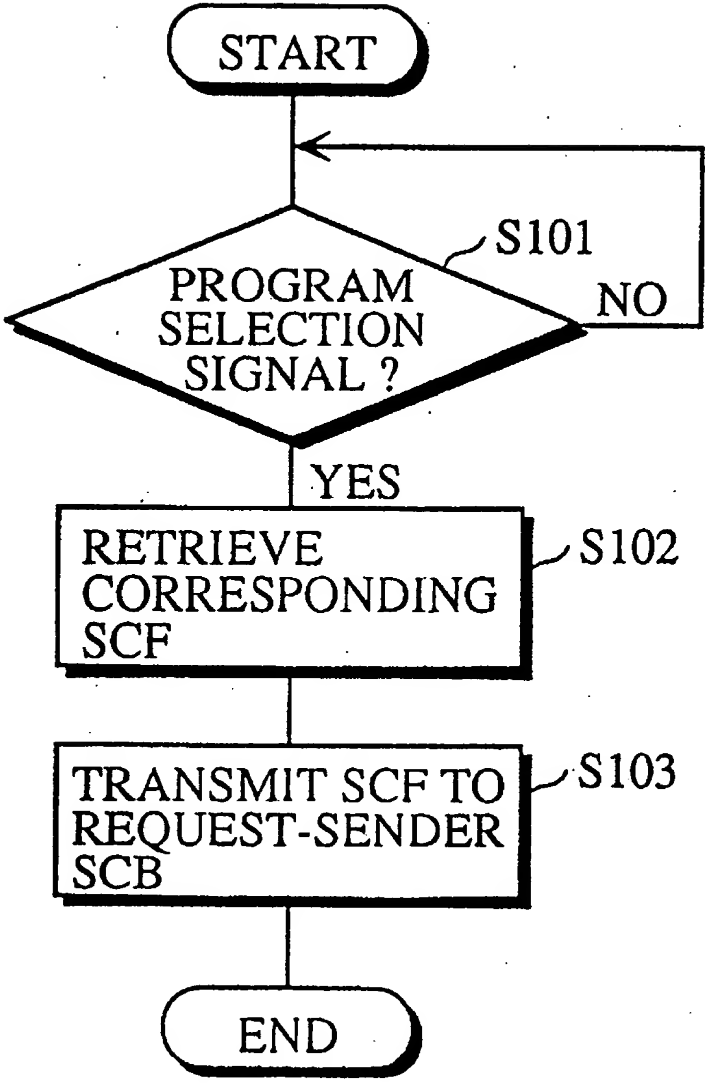

START
S101
PROGRAM SELECTION SIGNAL ?
NO
YES
RETRIEVE CORRESPONDING SCF
S102
TRANSMIT SCF TO REQUEST-SENDER SCB
S103
END

FIG. 8

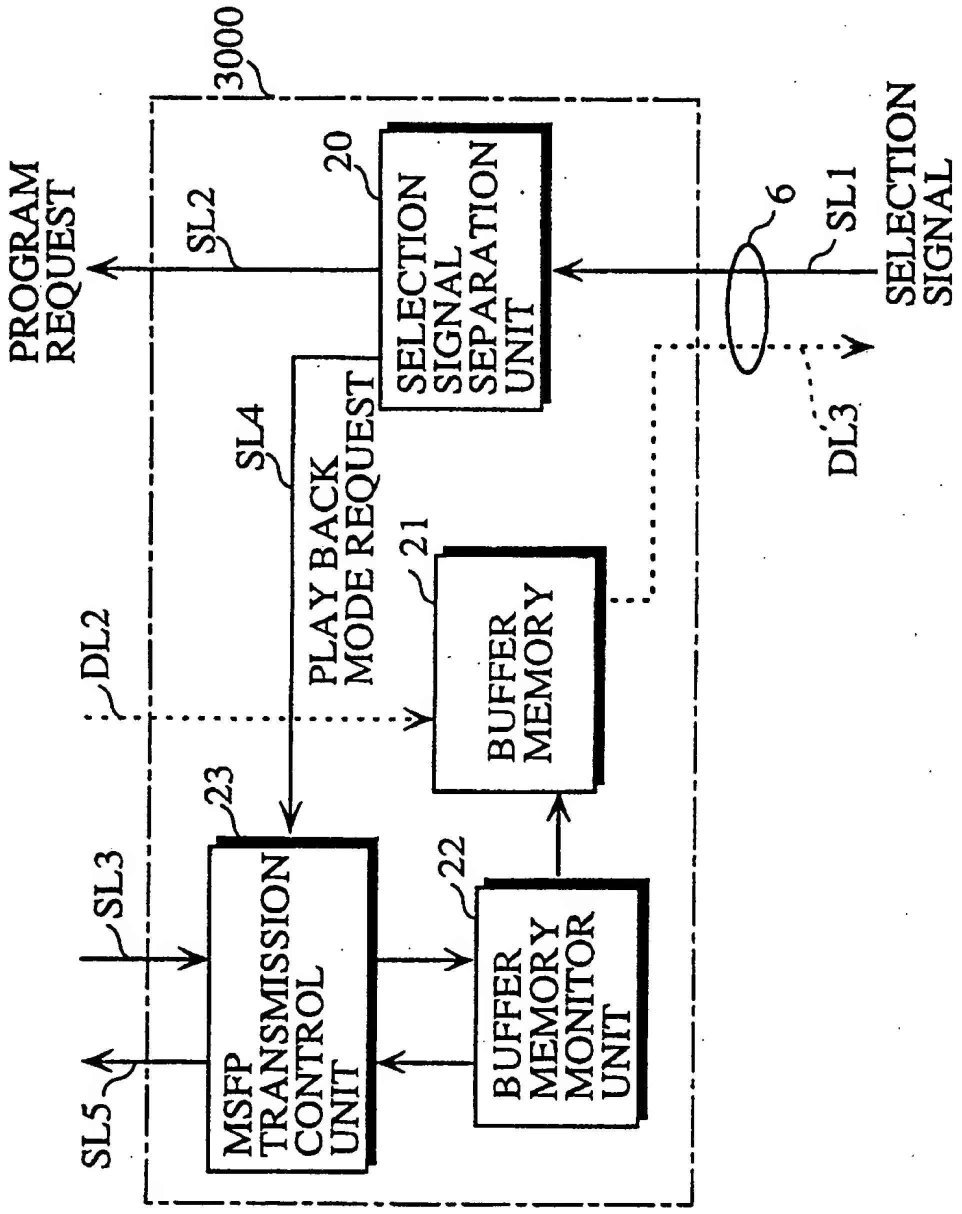

3000
PROGRAM REQUEST
SL2
20
SELECTION SIGNAL SEPARATION UNIT
6
SL1
SELECTION SIGNAL
DL3
SL4
PLAY BACK MODE REQUEST
21
BUFFER MEMORY
DL2
23
SL3
MSFP TRANSMISSION CONTROL UNIT
SL5
22
BUFFER MEMORY MONITOR UNIT

FIG. 9

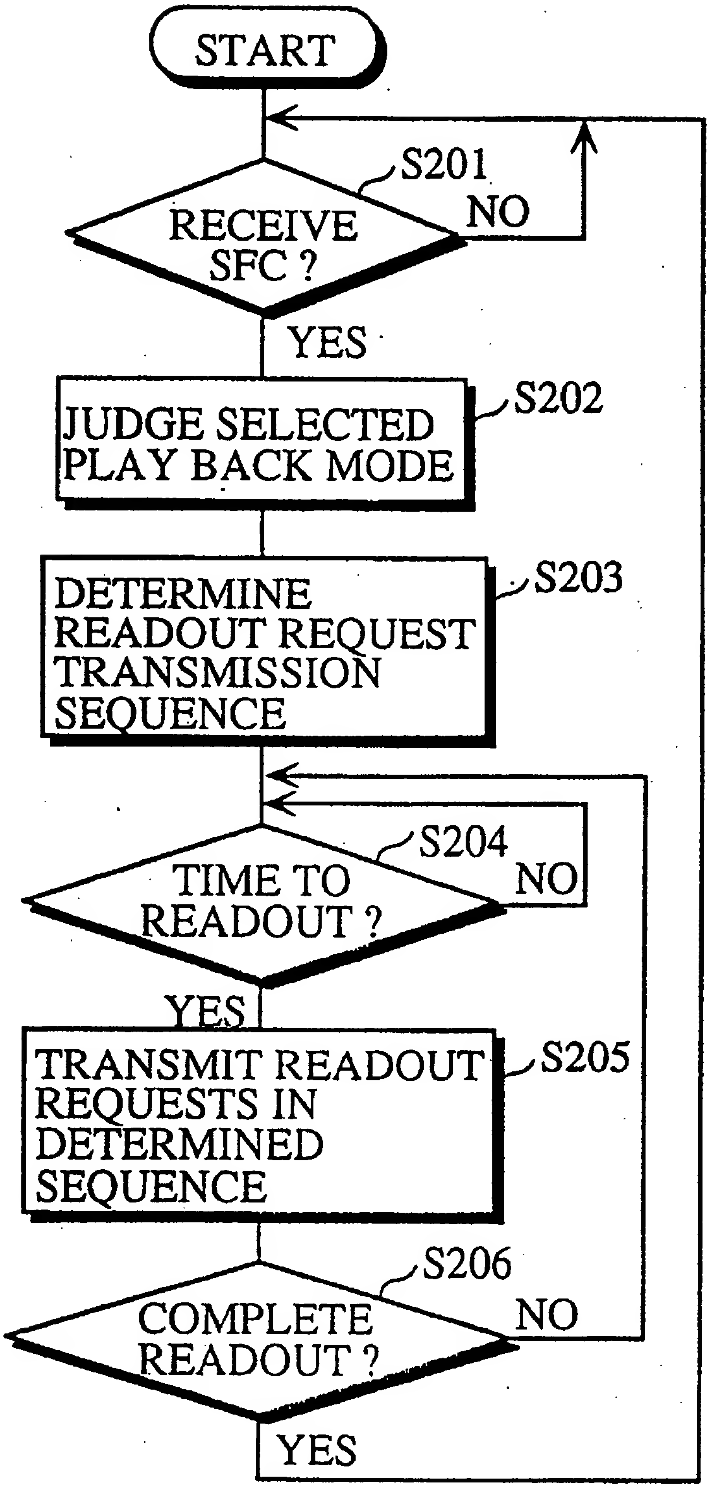

START
S201
RECEIVE SFC ?
NO
YES
JUDGE SELECTED PLAY BACK MODE
S202
DETERMINE READOUT REQUEST TRANSMISSION SEQUENCE
S203
S204
TIME TO READOUT ?
NO
YES
TRANSMIT READOUT REQUESTS IN DETERMINED SEQUENCE
S205
S206
COMPLETE READOUT ?
NO
YES

FIG. 10

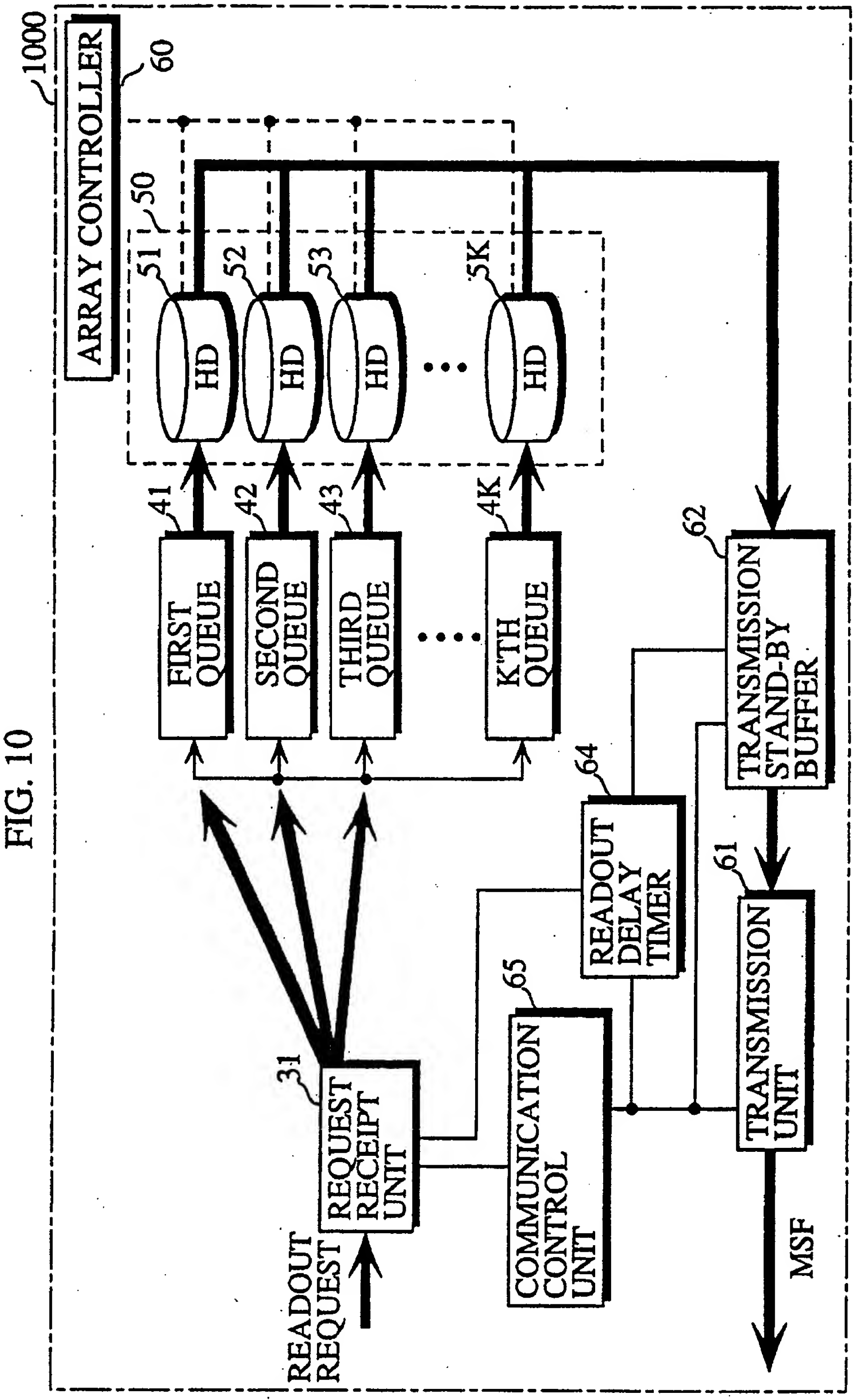

1000
ARRAY CONTROLLER
60
50
51
52
53
5K
HD
HD
HD
HD
41
42
43
4K
FIRST QUEUE
SECOND QUEUE
THIRD QUEUE
K'TH QUEUE
62
TRANSMISSION STAND-BY BUFFER
64
READOUT DELAY TIMER
61
TRANSMISSION UNIT
65
COMMUNICATION CONTROL UNIT
31
REQUEST RECEIPT UNIT
READOUT REQUEST
MSF

FIG. 11A

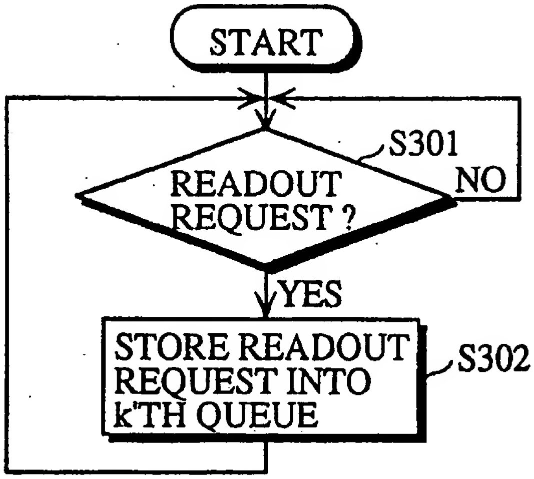
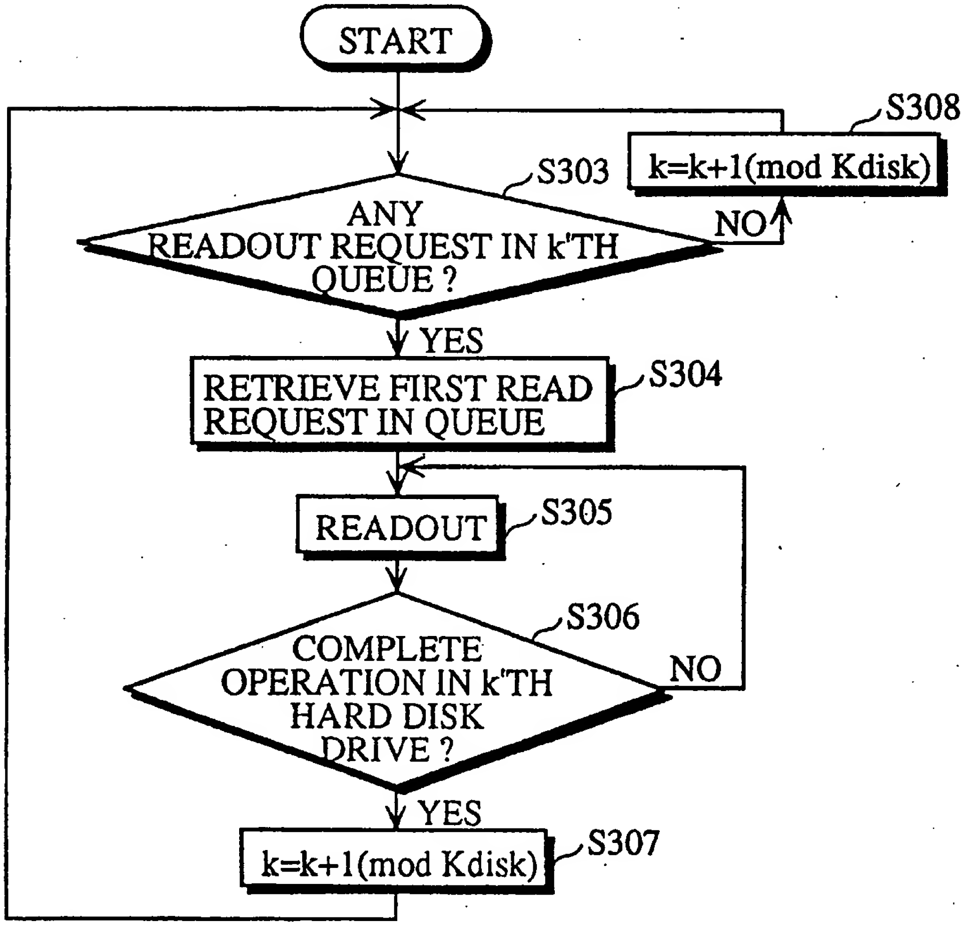


FIG. 11B


START
S308
k=k+1(mod Kdisk)
S303
ANY READOUT REQUEST IN k'TH QUEUE ?
NO
YES
RETRIEVE FIRST READ REQUEST IN QUEUE
S304
READOUT
S305
S306
COMPLETE OPERATION IN k'TH HARD DISK DRIVE ?
NO
YES
k=k+1(mod Kdisk)
S307

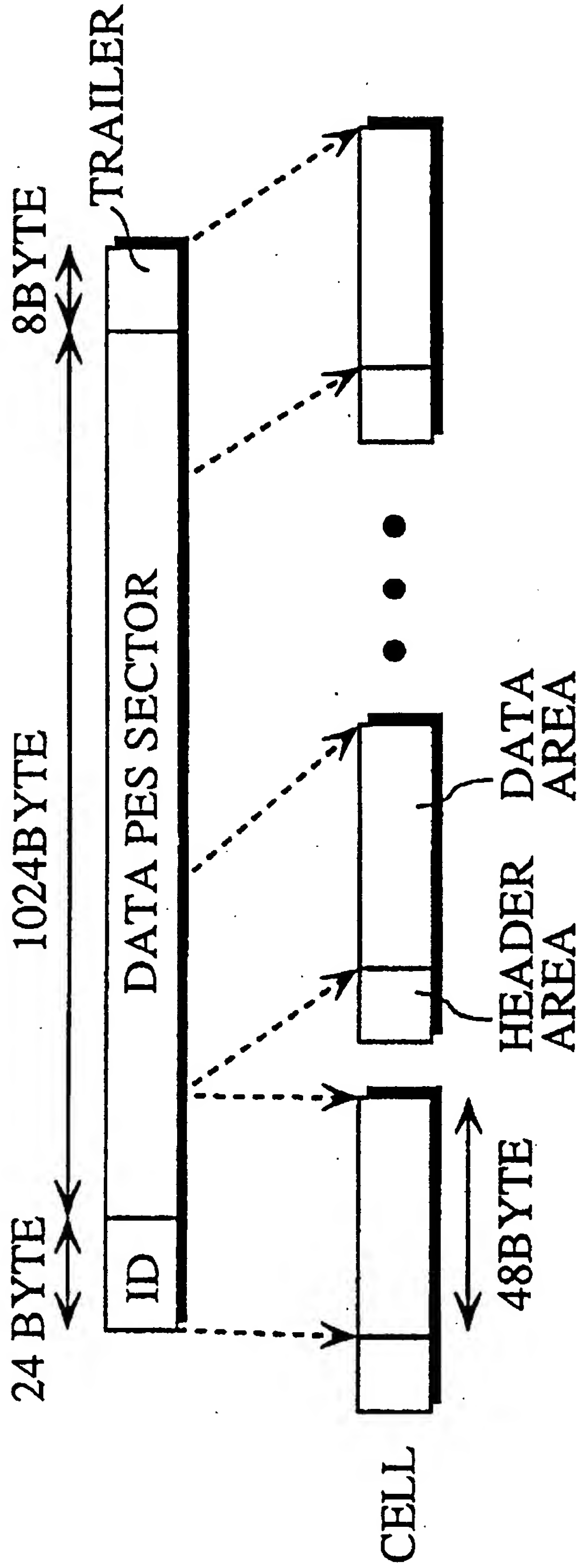

24 BYTE
1024BYTE
8BYTE
TRAILER
ID
DATA PES SECTOR
CELL
48BYTE
HEADER AREA
DATA AREA

FIG. 12

FIG. 13

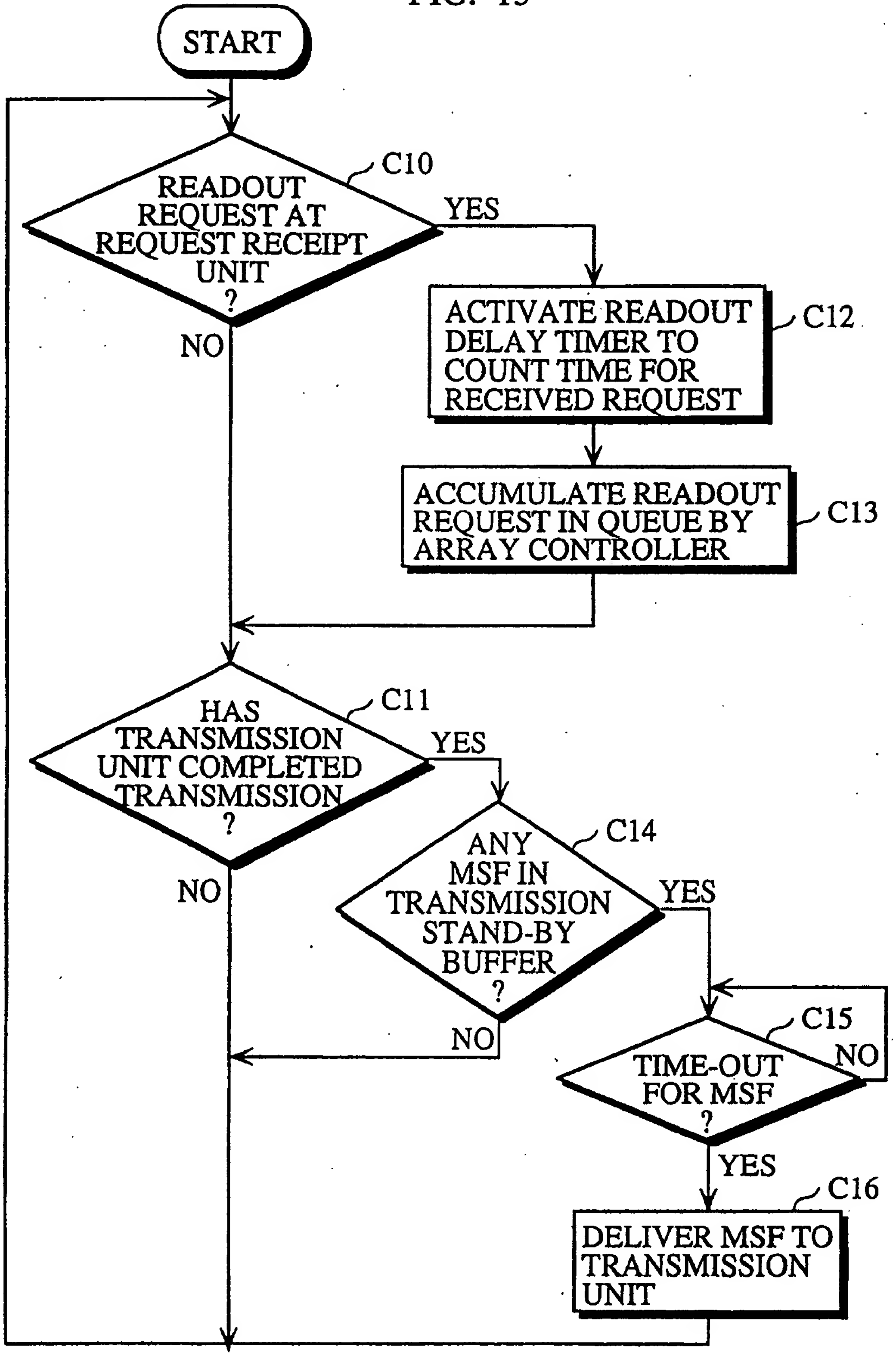

START
READOUT REQUEST AT REQUEST RECEIPT UNIT ?
C10
YES
NO
ACTIVATE READOUT DELAY TIMER TO COUNT TIME FOR RECEIVED REQUEST
C12
ACCUMULATE READOUT REQUEST IN QUEUE BY ARRAY CONTROLLER
C13
HAS TRANSMISSION UNIT COMPLETED TRANSMISSION ?
C11
YES
NO
ANY MSF IN TRANSMISSION STAND-BY BUFFER ?
C14
YES
NO
TIME-OUT FOR MSF ?
C15
NO
YES
DELIVER MSF TO TRANSMISSION UNIT
C16

FIG. 14

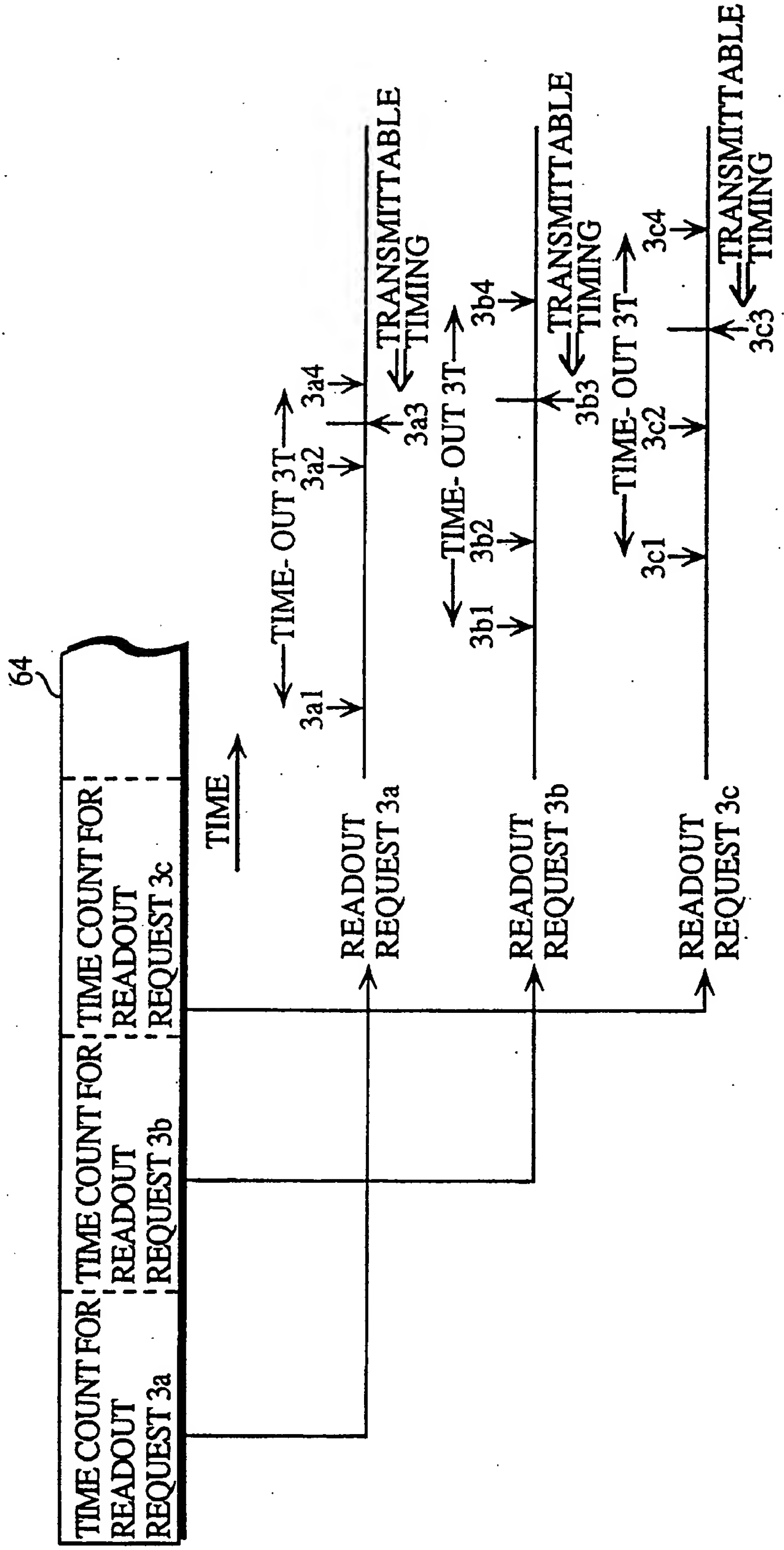
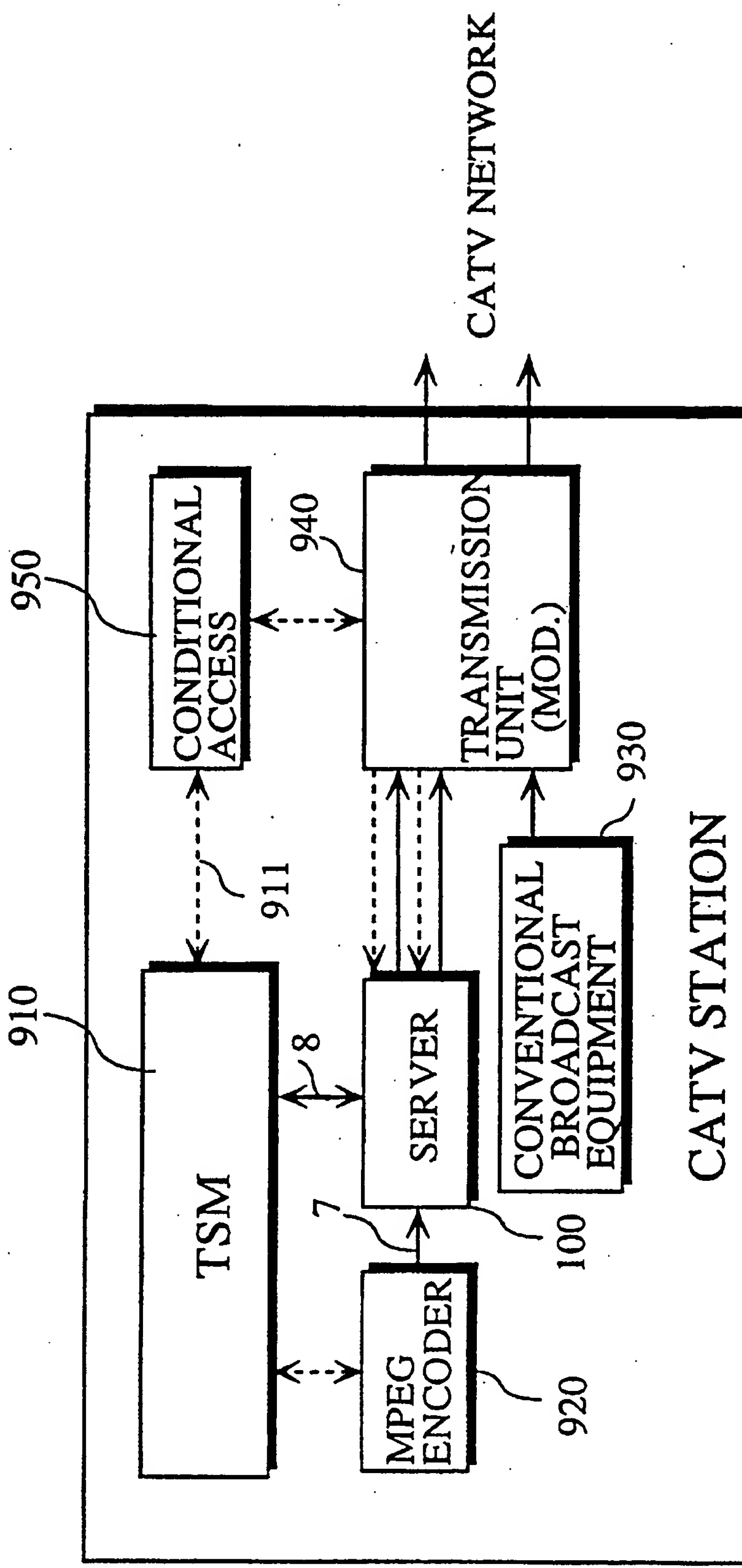

64
TIME COUNT FOR READOUT REQUEST 3a
TIME COUNT FOR READOUT REQUEST 3b
TIME COUNT FOR READOUT REQUEST 3c
TIME
READOUT REQUEST 3a
READOUT REQUEST 3b
READOUT REQUEST 3c
3a1
TIME- OUT 3T
3a2
3a3
3a4
TRANSMITTABLE TIMING
TRANSMITTABLE
3b1
3b2
TIME- OUT 3T
3b3
3b4
TRANSMITTABLE TIMING
TRANSMITTABLE
3c1
3c2
TIME- OUT 3T
3c3
3c4
TRANSMITTABLE TIMING
TRANSMITTABLE

FIG. 15


CATV NETWORK
950
CONDITIONAL ACCESS
940
TRANSMISSION UNIT (MOD.)
930
911
910
TSM
8
SERVER
7
100
MPEG ENCODER
920
CONVENTIONAL BROADCAST EQUIPMENT
CATV STATION

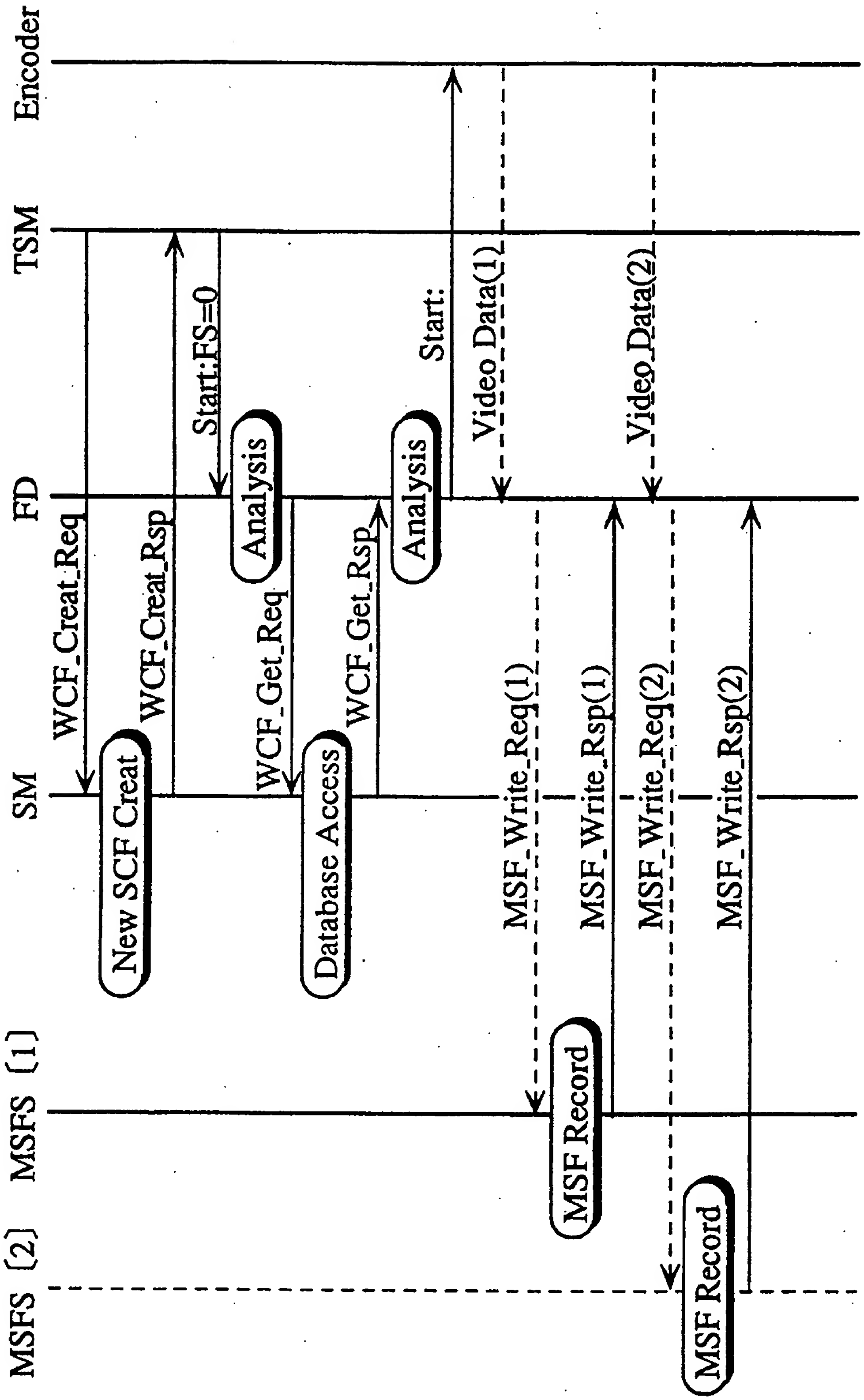

Encoder
TSM
FD
SM
MSFS 〔1〕
MSFS 〔2〕
WCF_Creat_Req
New SCF Creat
WCF_Creat_Rsp
Start:FS=0
Analysis
WCF_Get_Req
Database Access
WCF_Get_Rsp
Analysis
Start:
Video Data(1)
Video Data(2)
MSF_Write_Req(1)
MSF Record
MSF_Write_Rsp(1)
MSF_Write_Req(2)
MSF Record
MSF_Write_Rsp(2)

FIG. 16

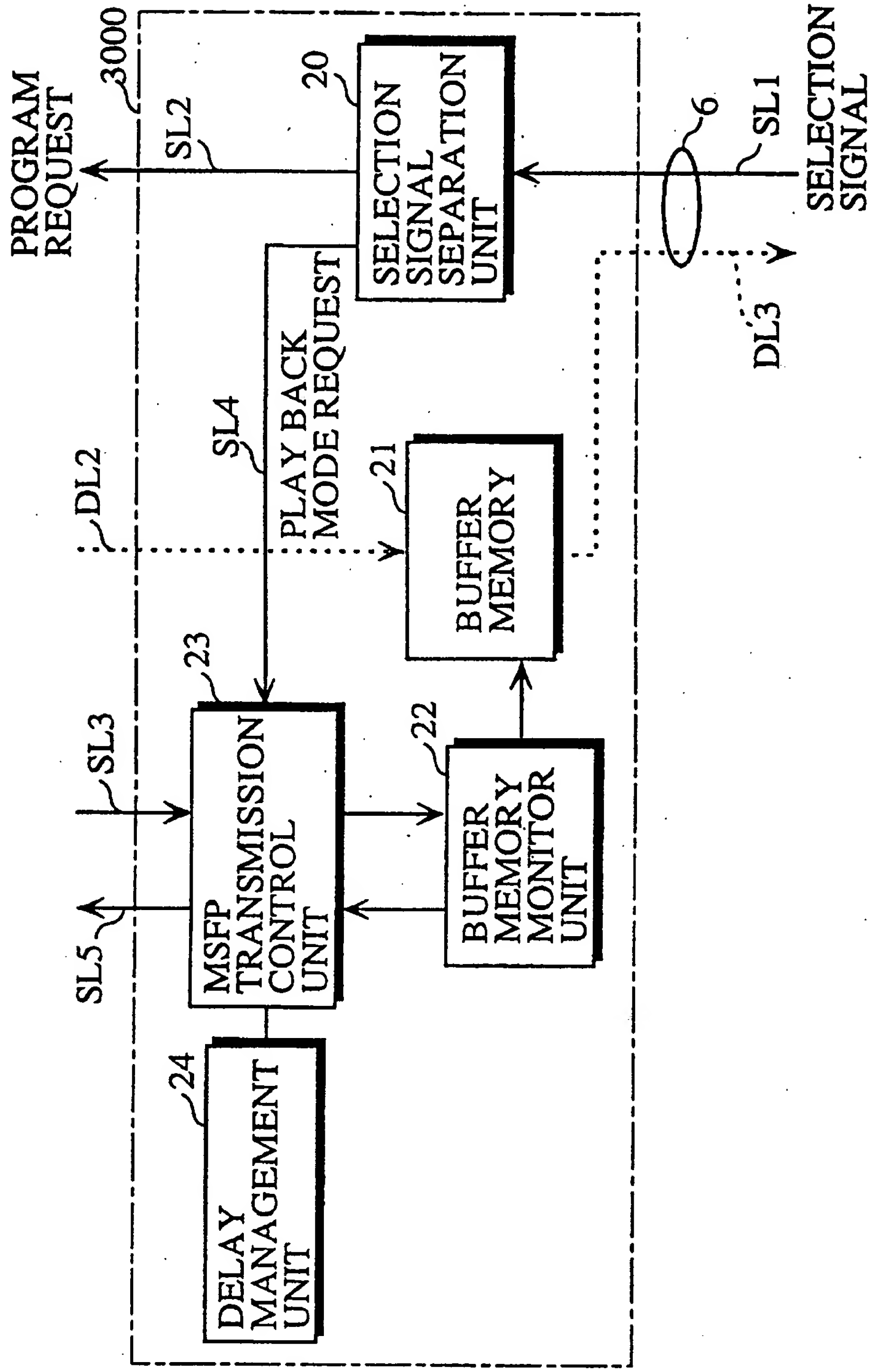
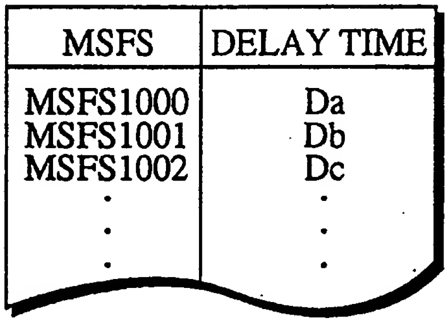

PROGRAM REQUEST
3000
SL2
20
SELECTION SIGNAL SEPARATION UNIT
6
SL1
SELECTION SIGNAL
DL3
SL4
PLAY BACK MODE REQUEST
21
BUFFER MEMORY
DL2
23
MSFP TRANSMISSION CONTROL UNIT
22
BUFFER MEMORY MONITOR UNIT
SL3
SL5
24
DELAY MANAGEMENT UNIT

FIG. 17

FIG. 18



MSFS	DELAY TIME
MSFS1000	Da
MSFS1001	Db
MSFS1002	Dc
.	.
.	.
.	.

FIG. 19

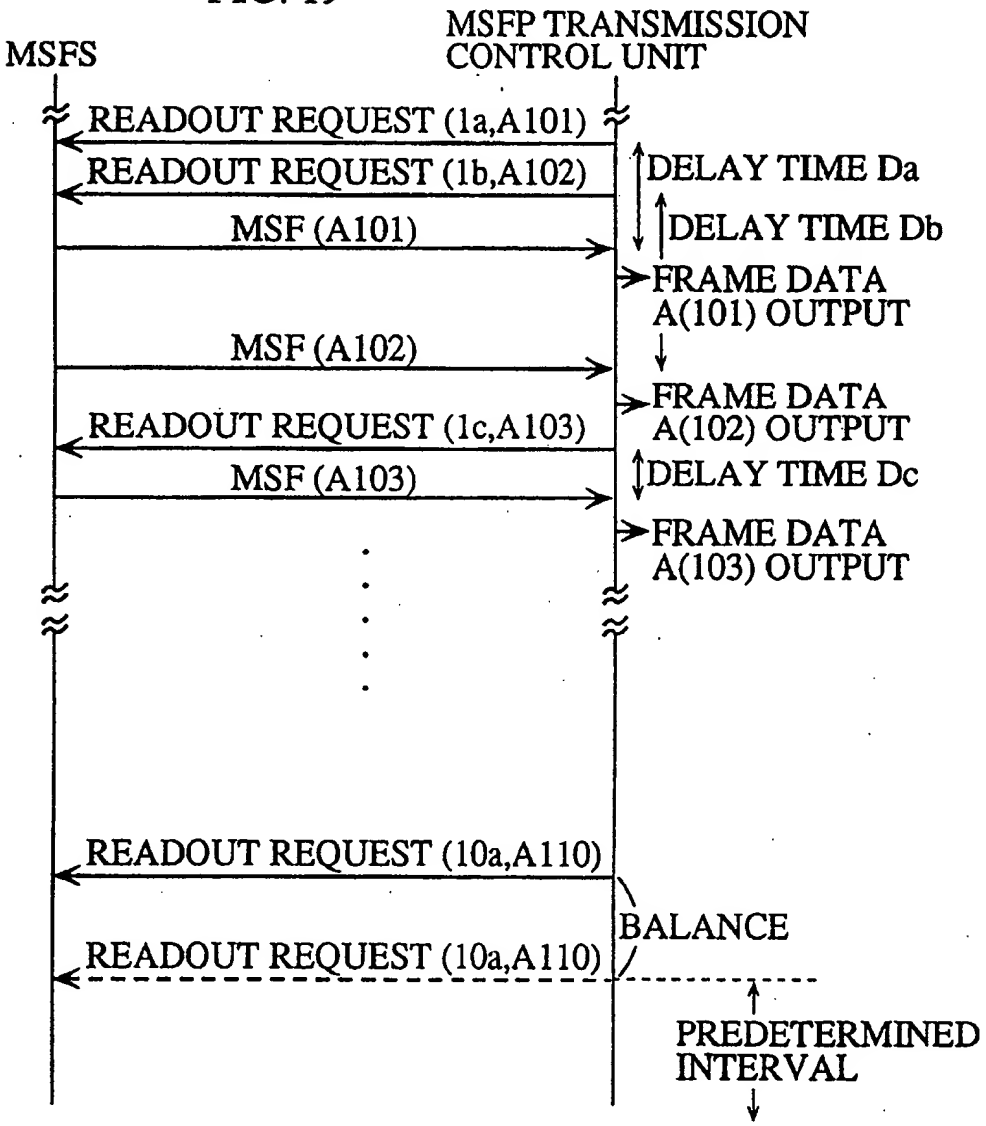


FIG. 20

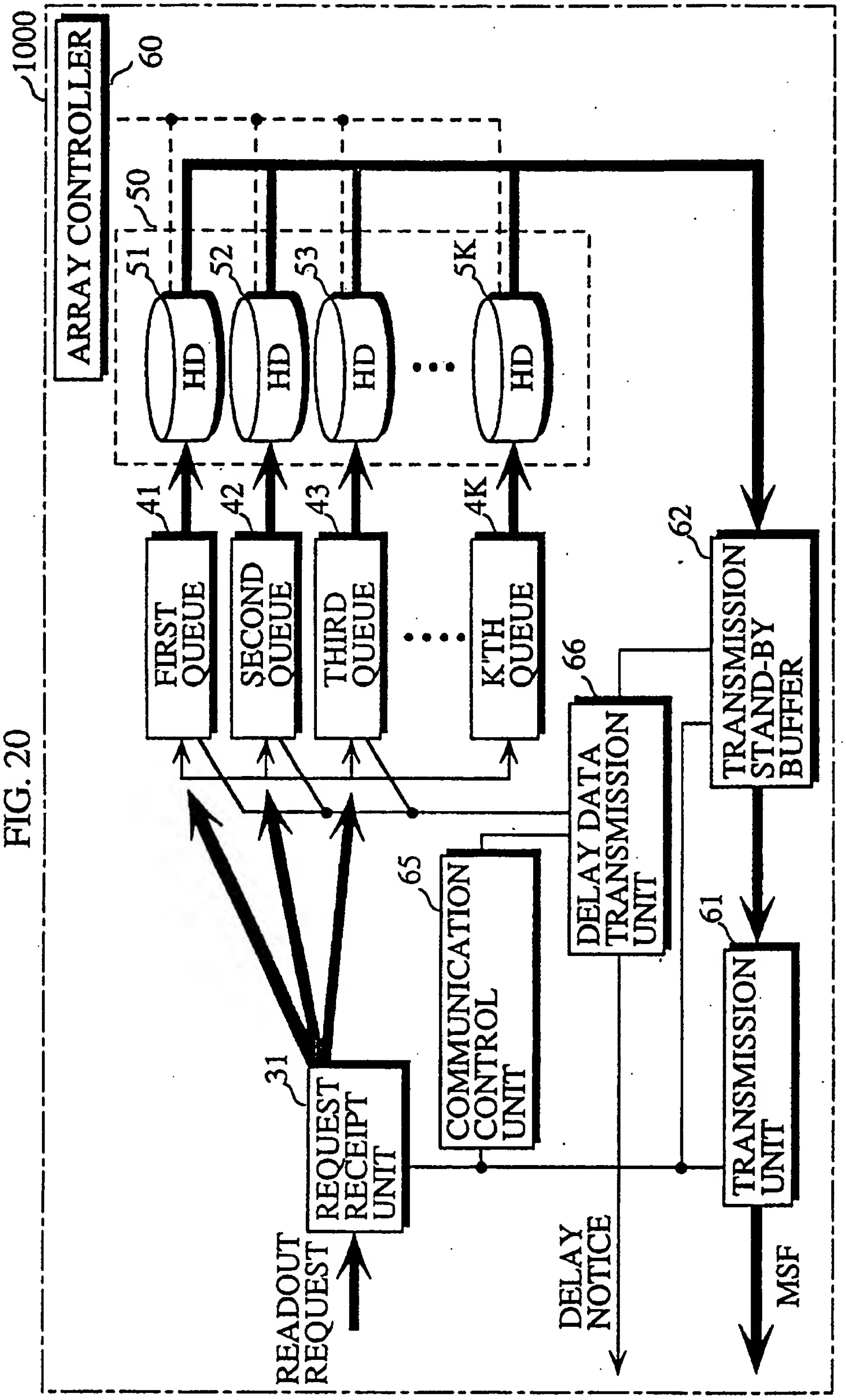

1000
ARRAY CONTROLLER
60
50
51
52
53
5K
HD
HD
HD
HD
41
42
43
4K
FIRST QUEUE
SECOND QUEUE
THIRD QUEUE
K'TH QUEUE
62
TRANSMISSION STAND-BY BUFFER
66
DELAY DATA TRANSMISSION UNIT
65
COMMUNICATION CONTROL UNIT
31
REQUEST RECEIPT UNIT
READOUT REQUEST
61
TRANSMISSION UNIT
DELAY NOTICE
MSF

FIG. 21

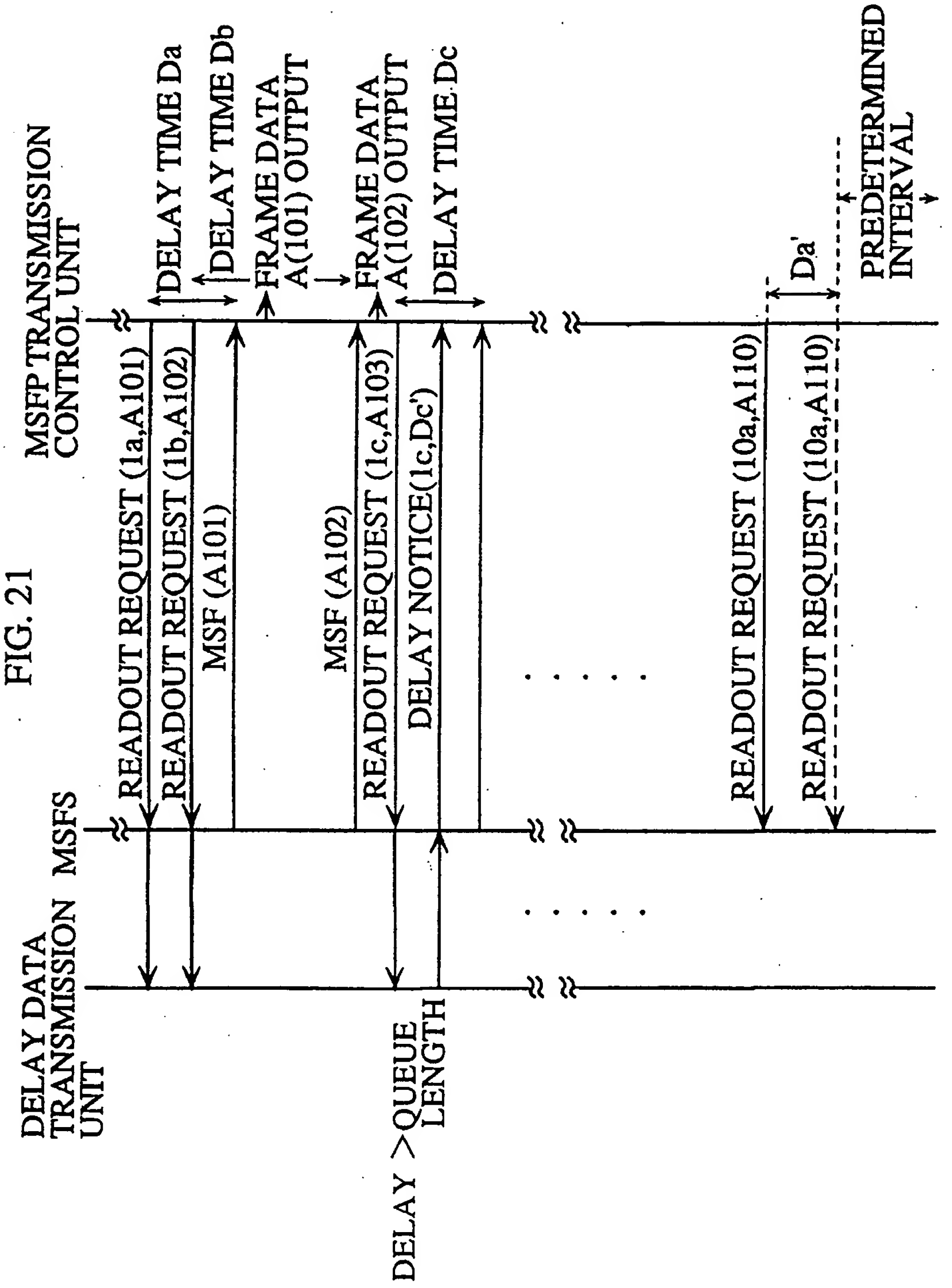

MSFP TRANSMISSION CONTROL UNIT
MSFS
DELAY DATA TRANSMISSION UNIT
READOUT REQUEST (1a,A101)
READOUT REQUEST (1b,A102)
MSF (A101)
MSF (A102)
READOUT REQUEST (1c,A103)
DELAY NOTICE(1c,Dc')
READOUT REQUEST (10a,A110)
READOUT REQUEST (10a,A110)
DELAY TIME Da
DELAY TIME Db
FRAME DATA A(101) OUTPUT
FRAME DATA A(102) OUTPUT
DELAY TIME Dc
Da'
PREDETERMINED INTERVAL
DELAY > QUEUE LENGTH

FIG. 22

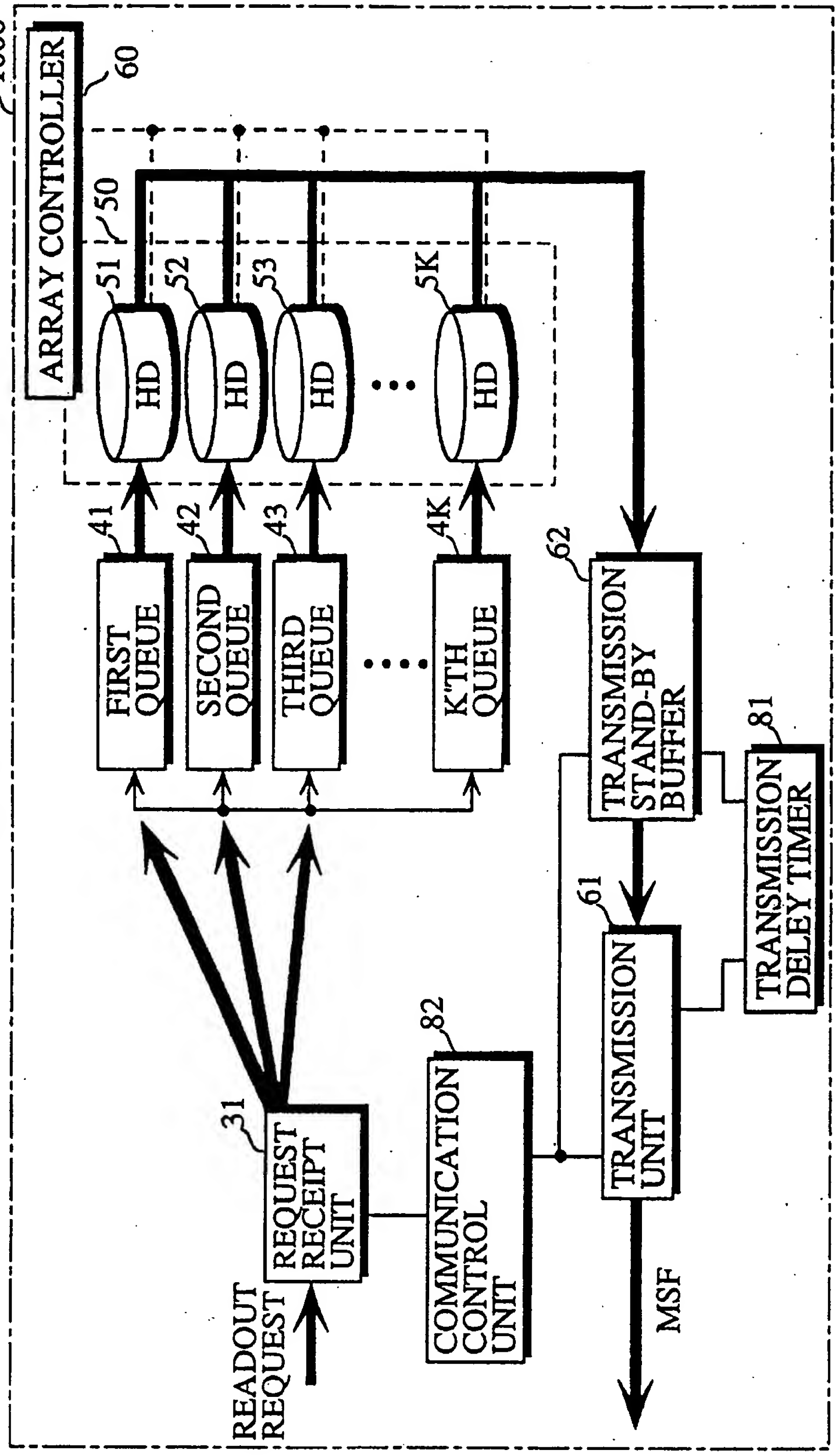

1000
ARRAY CONTROLLER
60
50
51
52
53
5K
HD
HD
HD
HD
41
42
43
4K
FIRST QUEUE
SECOND QUEUE
THIRD QUEUE
K'TH QUEUE
62
TRANSMISSION STAND-BY BUFFER
81
TRANSMISSION DELEY TIMER
61
TRANSMISSION UNIT
82
COMMUNICATION CONTROL UNIT
31
REQUEST RECEIPT UNIT
READOUT REQUEST
MSF

FIG. 23

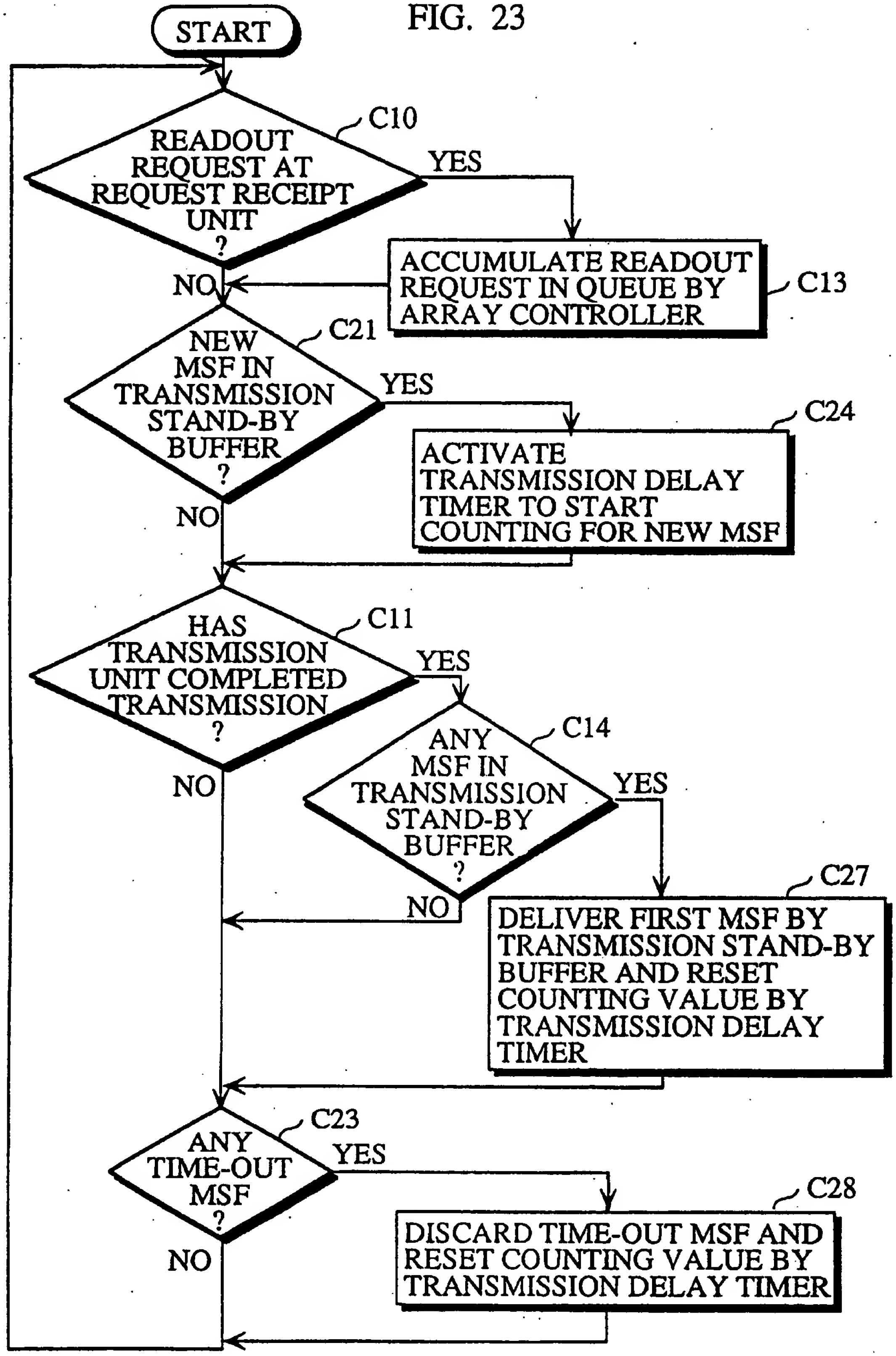

START
READOUT REQUEST AT REQUEST RECEIPT UNIT ?
C10
YES
NO
ACCUMULATE READOUT REQUEST IN QUEUE BY ARRAY CONTROLLER
C13
NEW MSF IN TRANSMISSION STAND-BY BUFFER ?
C21
YES
NO
ACTIVATE TRANSMISSION DELAY TIMER TO START COUNTING FOR NEW MSF
C24
HAS TRANSMISSION UNIT COMPLETED TRANSMISSION ?
C11
YES
NO
ANY MSF IN TRANSMISSION STAND-BY BUFFER ?
C14
YES
NO
DELIVER FIRST MSF BY TRANSMISSION STAND-BY BUFFER AND RESET COUNTING VALUE BY TRANSMISSION DELAY TIMER
C27
ANY TIME-OUT MSF ?
C23
YES
NO
DISCARD TIME-OUT MSF AND RESET COUNTING VALUE BY TRANSMISSION DELAY TIMER
C28

FIG. 24

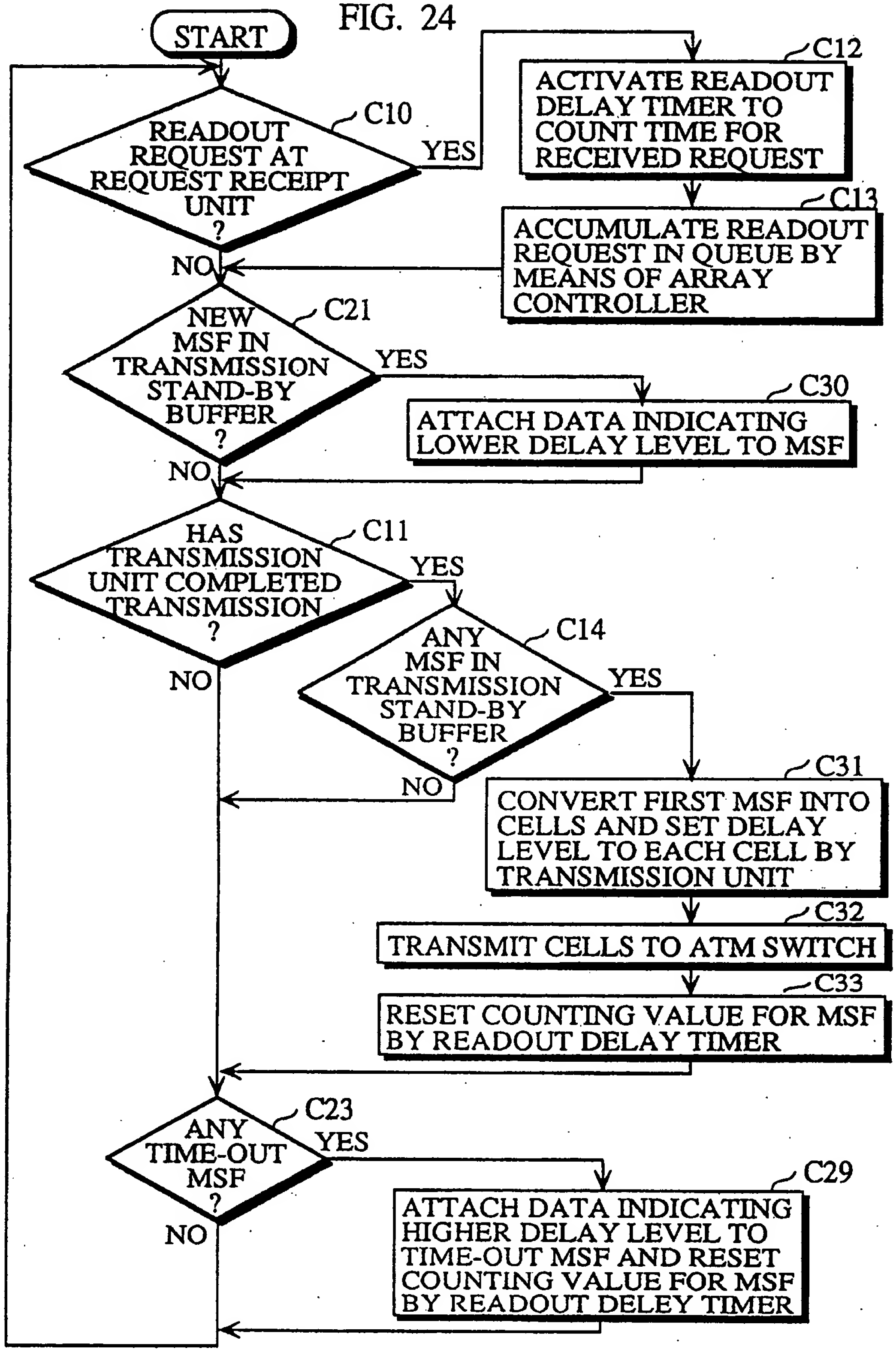

START
READOUT REQUEST AT REQUEST RECEIPT UNIT ?
C10
YES
NO
C12
ACTIVATE READOUT DELAY TIMER TO COUNT TIME FOR RECEIVED REQUEST
C13
ACCUMULATE READOUT REQUEST IN QUEUE BY MEANS OF ARRAY CONTROLLER
NEW MSF IN TRANSMISSION STAND-BY BUFFER ?
C21
YES
NO
C30
ATTACH DATA INDICATING LOWER DELAY LEVEL TO MSF
HAS TRANSMISSION UNIT COMPLETED TRANSMISSION ?
C11
YES
NO
ANY MSF IN TRANSMISSION STAND-BY BUFFER ?
C14
YES
NO
C31
CONVERT FIRST MSF INTO CELLS AND SET DELAY LEVEL TO EACH CELL BY TRANSMISSION UNIT
C32
TRANSMIT CELLS TO ATM SWITCH
C33
RESET COUNTING VALUE FOR MSF BY READOUT DELAY TIMER
ANY TIME-OUT MSF ?
C23
YES
NO
C29
ATTACH DATA INDICATING HIGHER DELAY LEVEL TO TIME-OUT MSF AND RESET COUNTING VALUE FOR MSF BY READOUT DELEY TIMER

FIG. 25

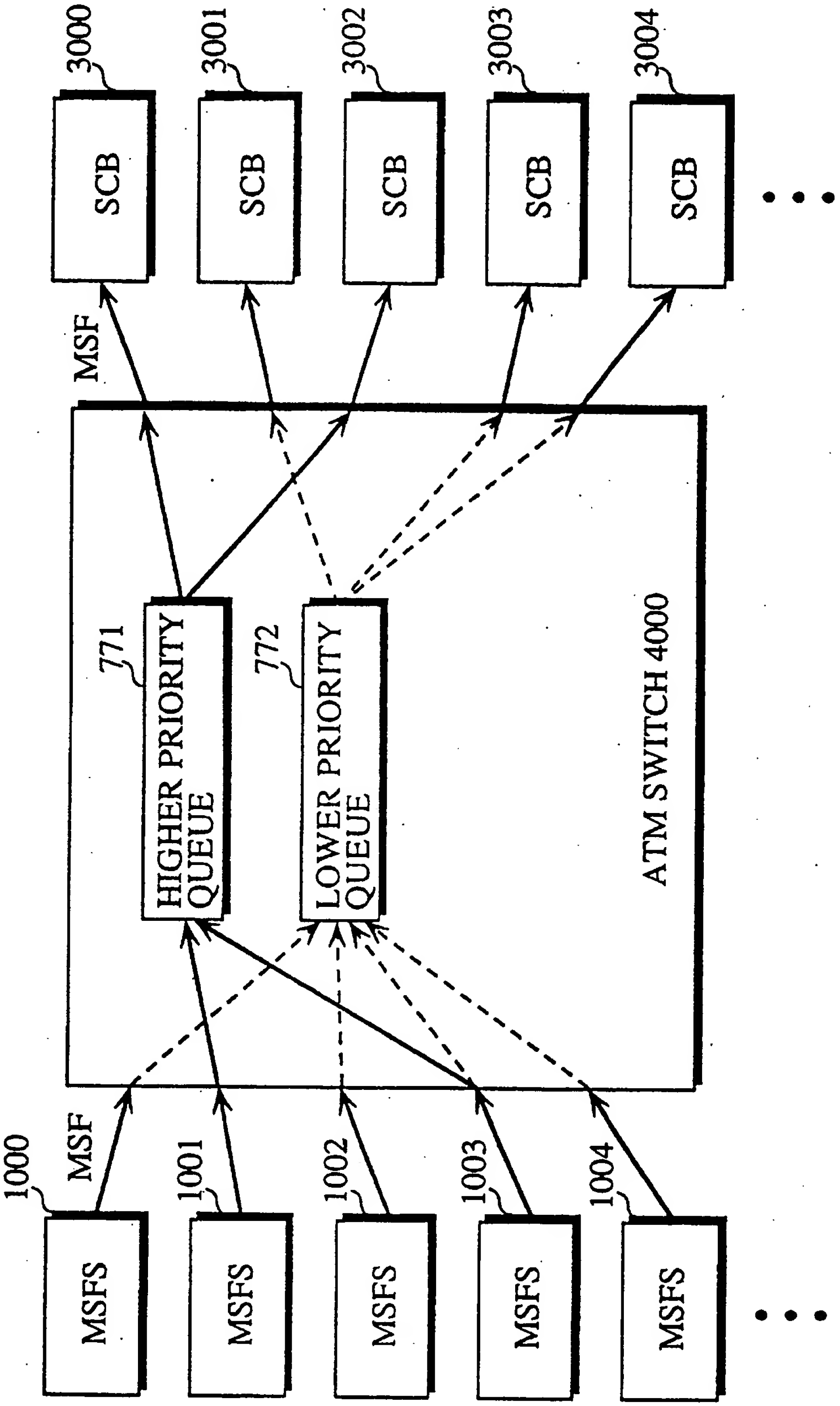

3000
3001
3002
3003
3004
SCB
SCB
SCB
SCB
SCB
MSF
771
HIGHER PRIORITY QUEUE
772
LOWER PRIORITY QUEUE
ATM SWITCH 4000
MSF
1000
1001
1002
1003
1004
MSFS
MSFS
MSFS
MSFS
MSFS

FIG. 26

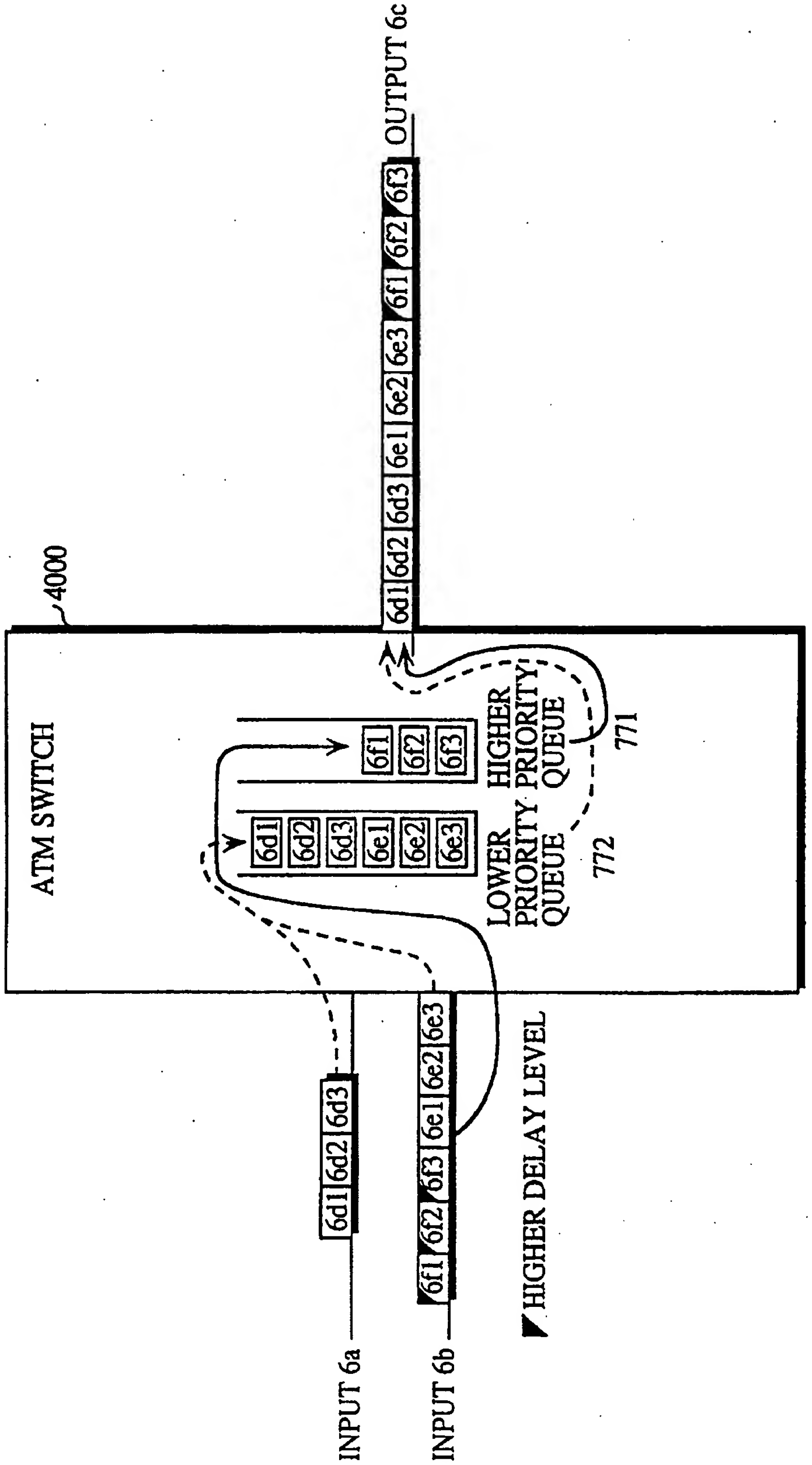

OUTPUT 6c
6d1
6d2
6d3
6e1
6e2
6e3
6f1
6f2
6f3
4000
ATM SWITCH
6f1
6f2
6f3
HIGHER PRIORITY QUEUE
771
6d1
6d2
6d3
6e1
6e2
6e3
LOWER PRIORITY QUEUE
772
6d1
6d2
6d3
INPUT 6a
6f1
6f2
6f3
6e1
6e2
6e3
INPUT 6b
HIGHER DELAY LEVEL

FIG. 27

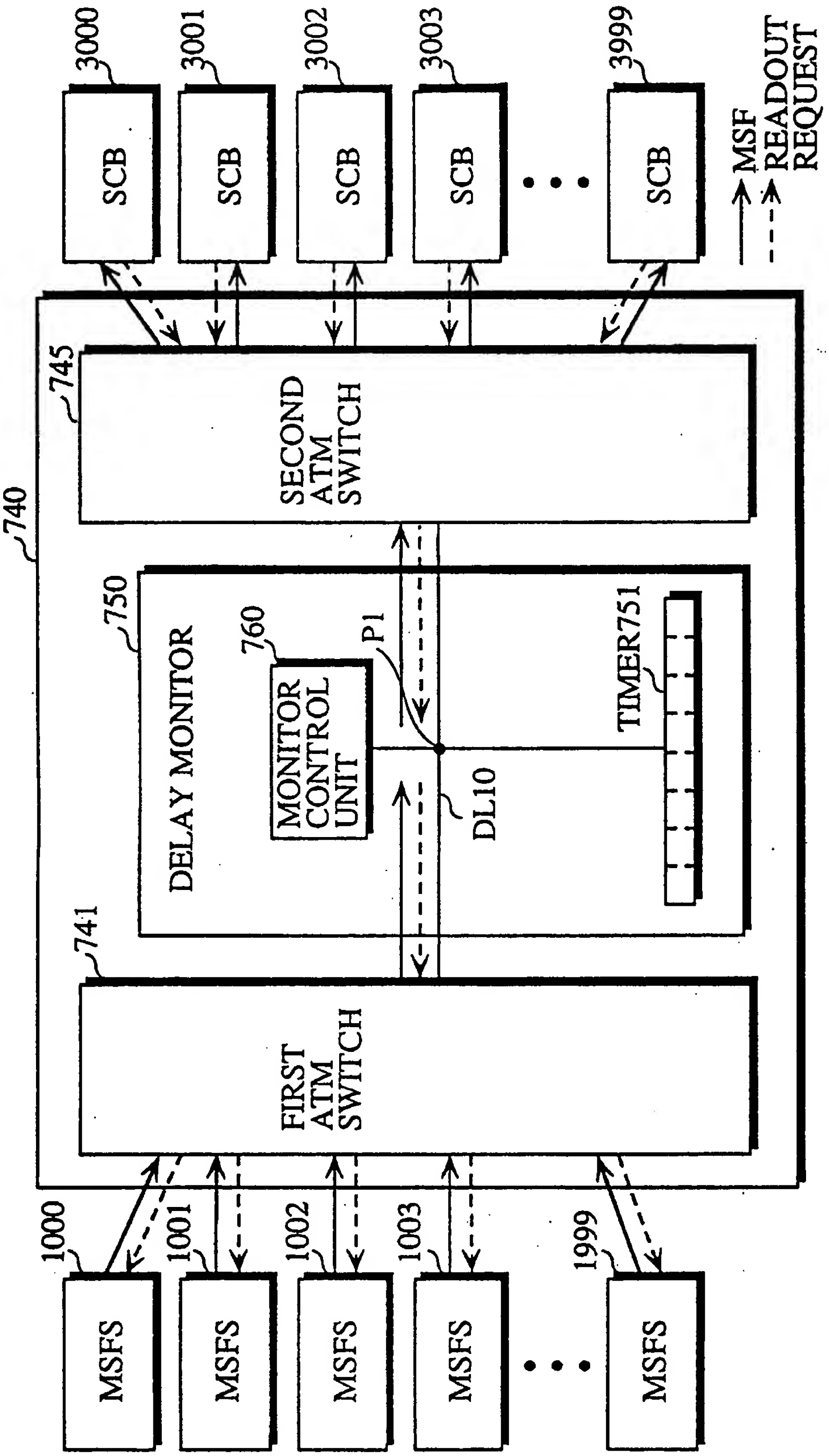

3000
3001
3002
3003
3999
SCB
SCB
SCB
SCB
SCB
MSF
READOUT REQUEST
745
SECOND ATM SWITCH
740
750
DELAY MONITOR
760
MONITOR CONTROL UNIT
P1
DL10
TIMER751
741
FIRST ATM SWITCH
1000
1001
1002
1003
1999
MSFS
MSFS
MSFS
MSFS
MSFS

FIG. 28

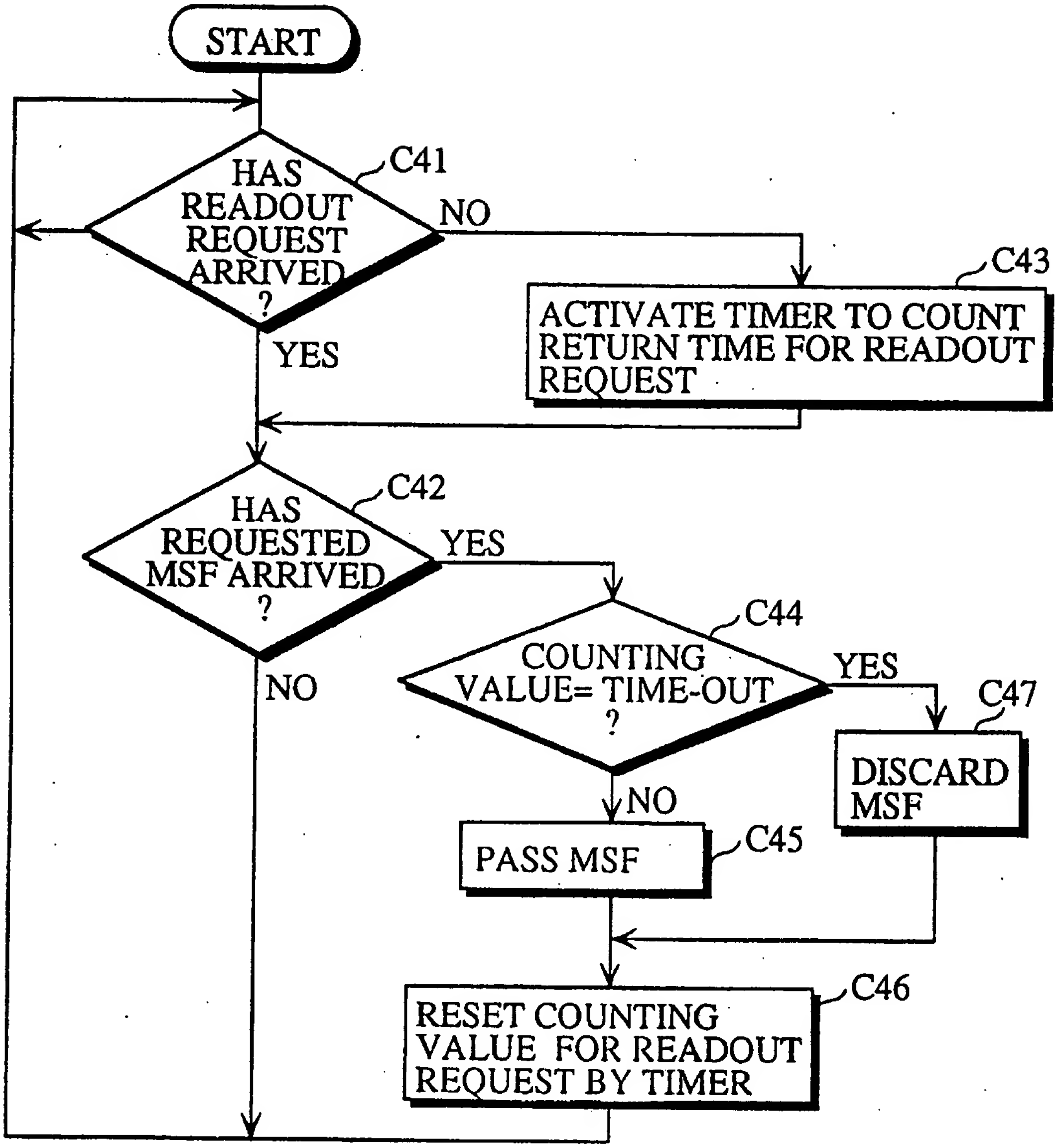

START
HAS READOUT REQUEST ARRIVED ?
C41
NO
YES
ACTIVATE TIMER TO COUNT RETURN TIME FOR READOUT REQUEST
C43
HAS REQUESTED MSF ARRIVED ?
C42
YES
NO
COUNTING VALUE= TIME-OUT ?
C44
YES
NO
DISCARD MSF
C47
PASS MSF
C45
RESET COUNTING VALUE FOR READOUT REQUEST BY TIMER
C46

FIG. 29

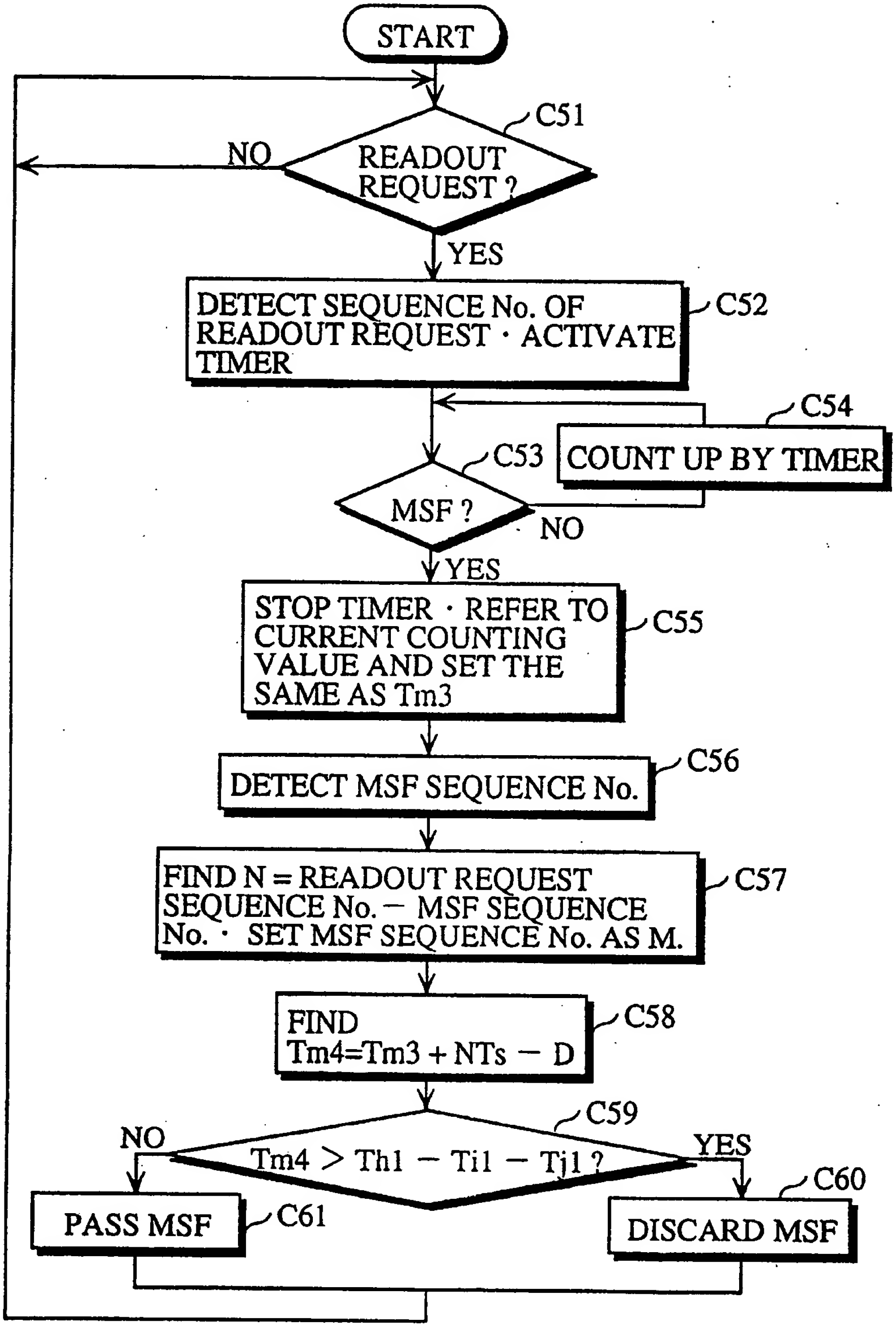
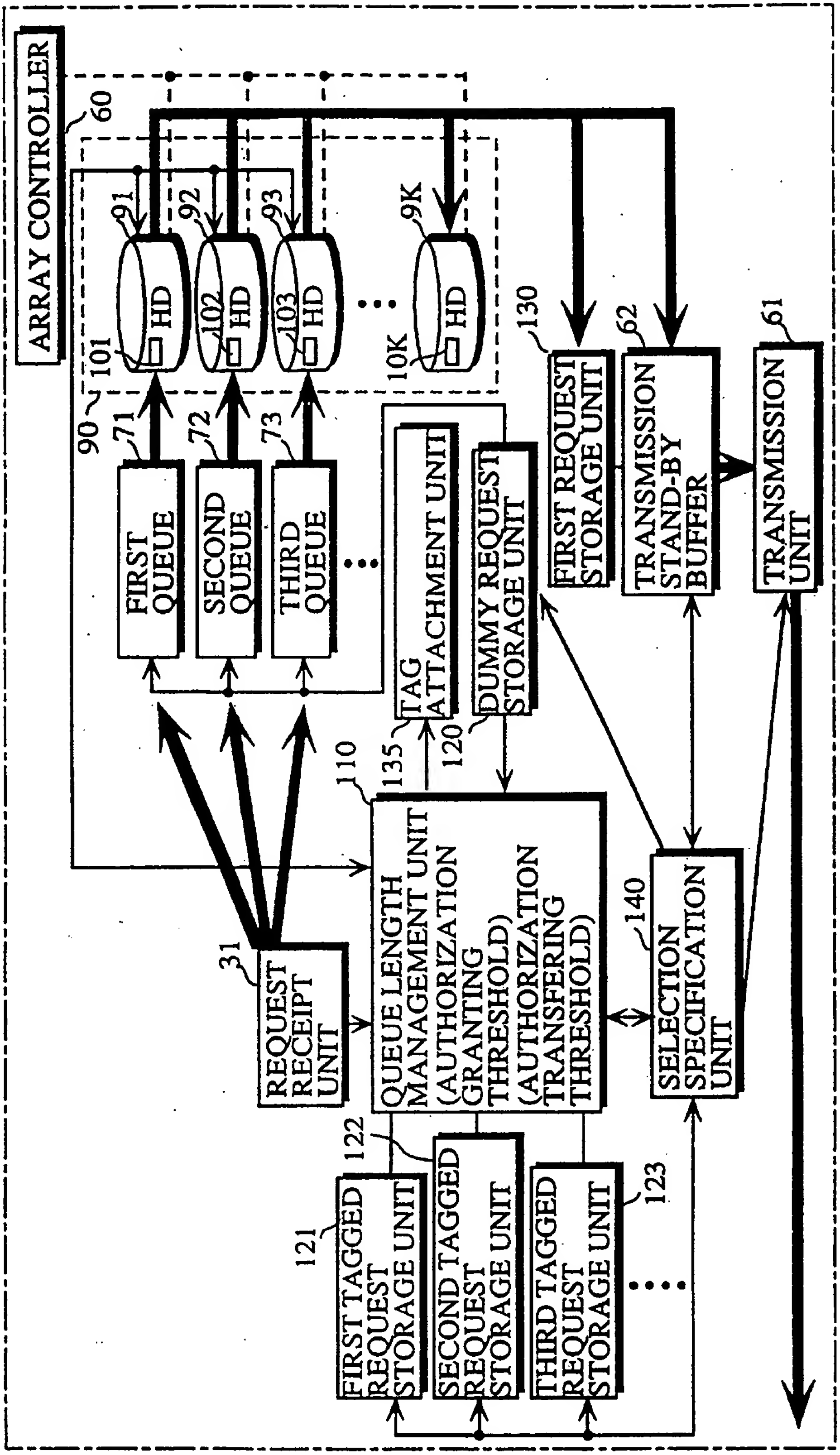

START
C51
READOUT REQUEST ?
NO
YES
DETECT SEQUENCE No. OF READOUT REQUEST · ACTIVATE TIMER
C52
C54
COUNT UP BY TIMER
C53
MSF ?
NO
YES
STOP TIMER · REFER TO CURRENT COUNTING VALUE AND SET THE SAME AS Tm3
C55
DETECT MSF SEQUENCE No.
C56
FIND N = READOUT REQUEST SEQUENCE No. − MSF SEQUENCE No. · SET MSF SEQUENCE No. AS M.
C57
FIND Tm4=Tm3 + NTs − D
C58
C59
NO
Tm4 > Th1 − Ti1 − Tj1 ?
YES
C60
PASS MSF
C61
DISCARD MSF

FIG. 30


ARRAY CONTROLLER
60
90
91
92
93
9K
HD
101
102
103
10K
71
72
73
FIRST QUEUE
SECOND QUEUE
THIRD QUEUE
130
FIRST REQUEST STORAGE UNIT
62
TRANSMISSION STAND-BY BUFFER
61
TRANSMISSION UNIT
TAG ATTACHMENT UNIT
DUMMY REQUEST STORAGE UNIT
135
120
110
QUEUE LENGTH MANAGEMENT UNIT (AUTHORIZATION GRANTING THRESHOLD) (AUTHORIZATION TRANSFERING THRESHOLD)
31
REQUEST RECEIPT UNIT
140
SELECTION SPECIFICATION UNIT
121
FIRST TAGGED REQUEST STORAGE UNIT
122
SECOND TAGGED REQUEST STORAGE UNIT
123
THIRD TAGGED REQUEST STORAGE UNIT

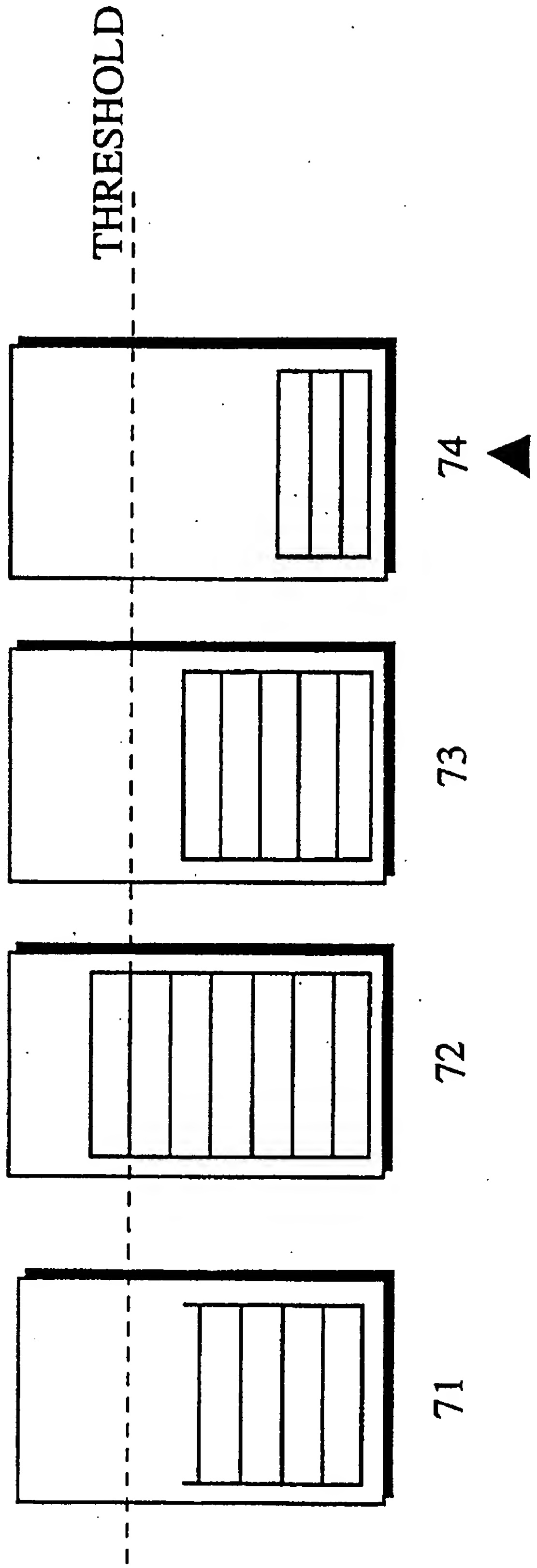


FIG. 31A

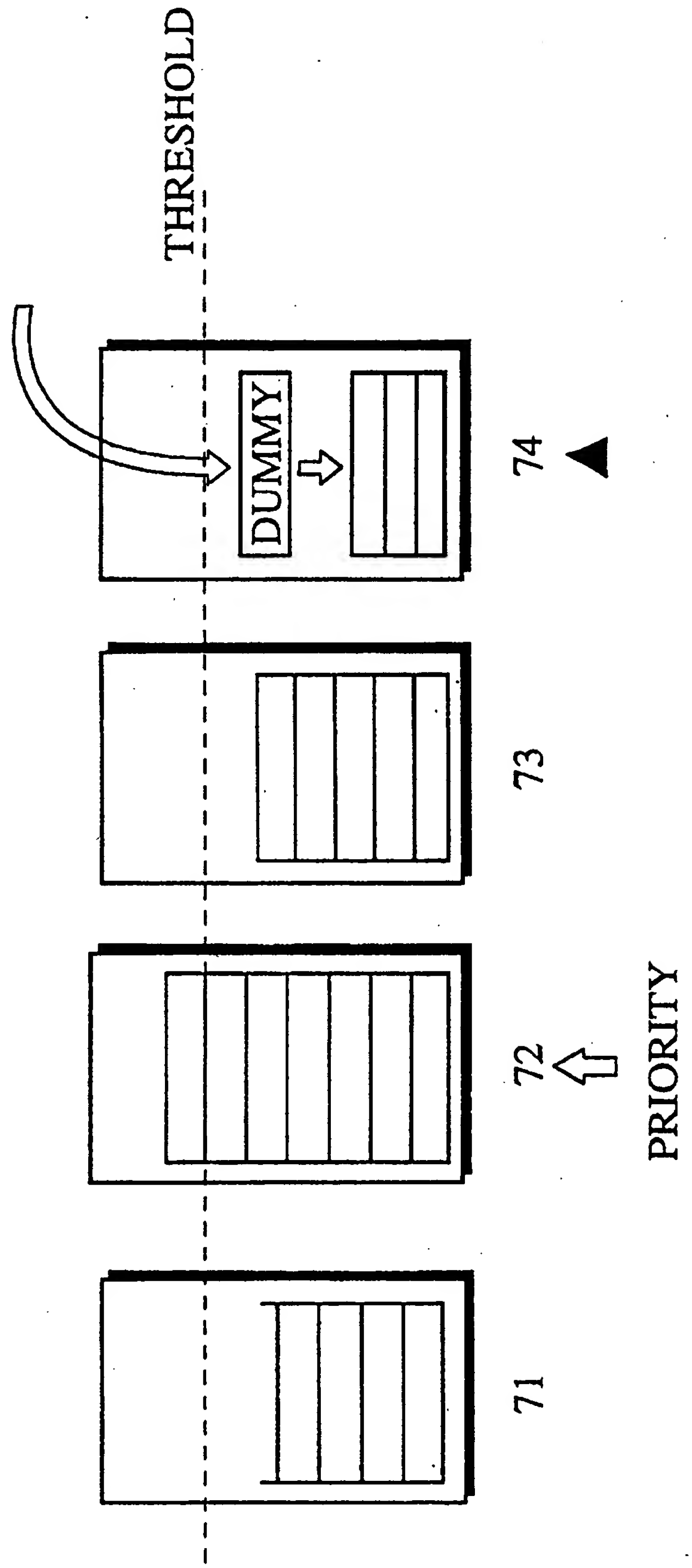


FIG. 31B

FIG. 32

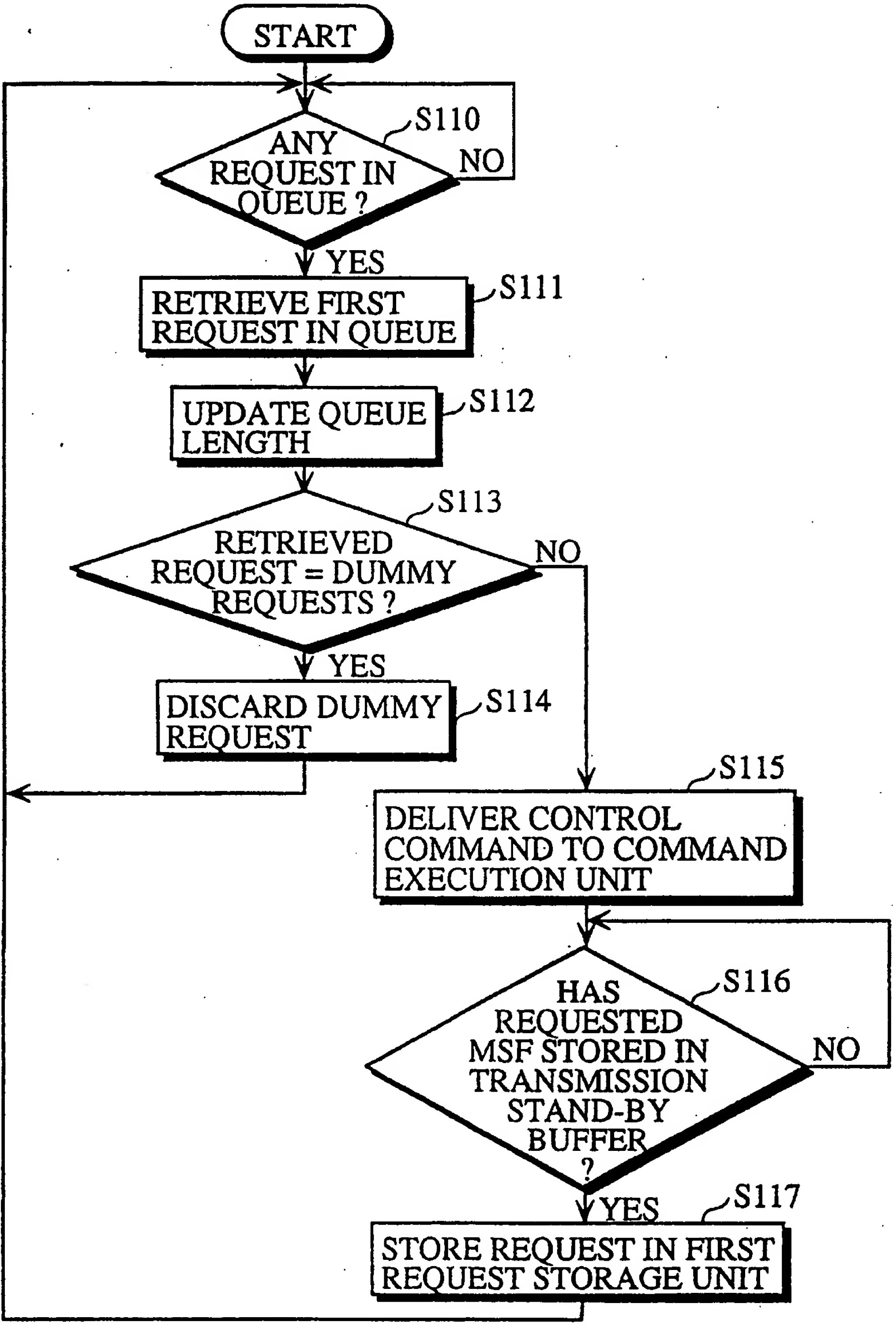

START
ANY REQUEST IN QUEUE ?
S110
NO
YES
RETRIEVE FIRST REQUEST IN QUEUE
S111
UPDATE QUEUE LENGTH
S112
RETRIEVED REQUEST = DUMMY REQUESTS ?
S113
NO
YES
DISCARD DUMMY REQUEST
S114
DELIVER CONTROL COMMAND TO COMMAND EXECUTION UNIT
S115
HAS REQUESTED MSF STORED IN TRANSMISSION STAND-BY BUFFER ?
S116
NO
YES
S117
STORE REQUEST IN FIRST REQUEST STORAGE UNIT

FIG. 33

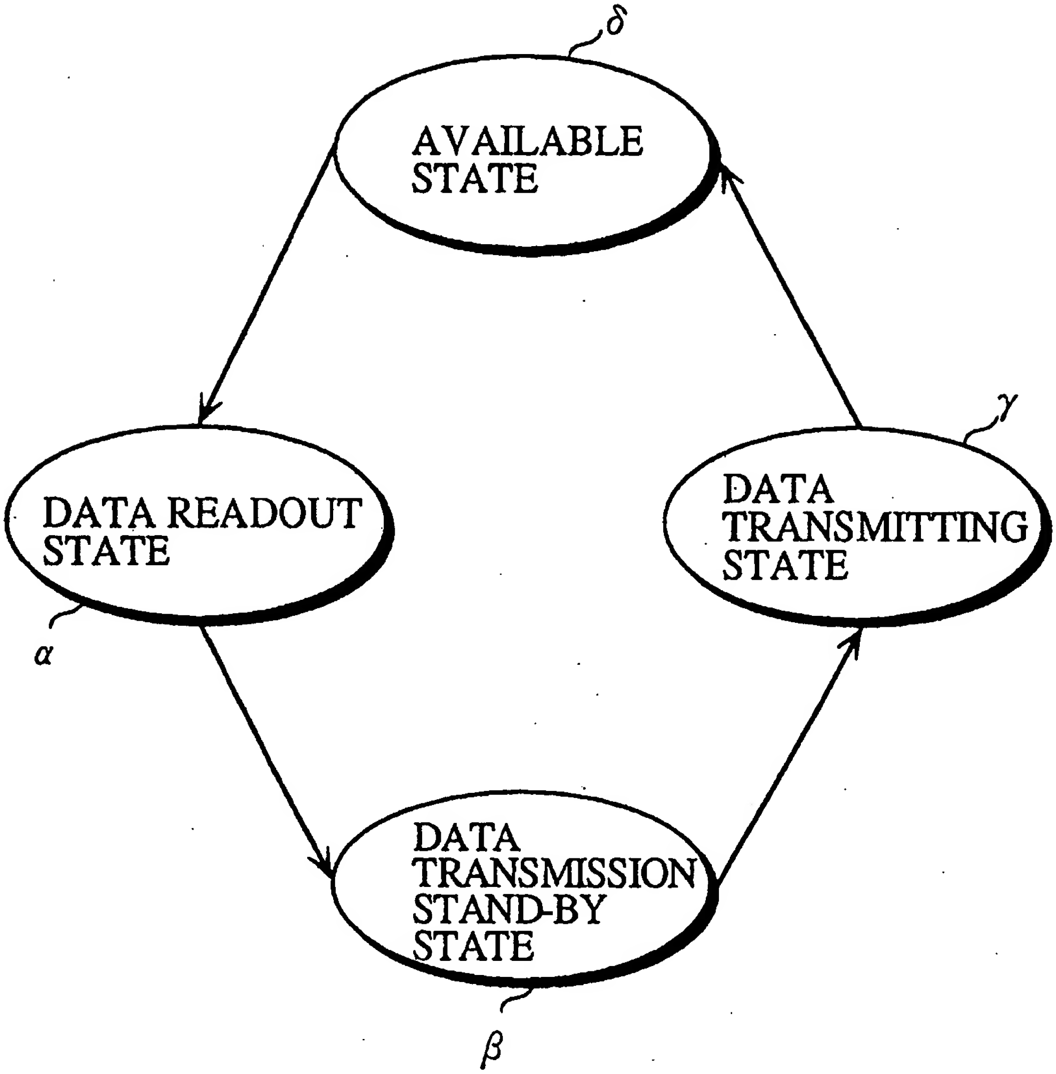

δ
AVAILABLE STATE
DATA READOUT STATE
α
γ
DATA TRANSMITTING STATE
DATA TRANSMISSION STAND-BY STATE
β

FIG. 34

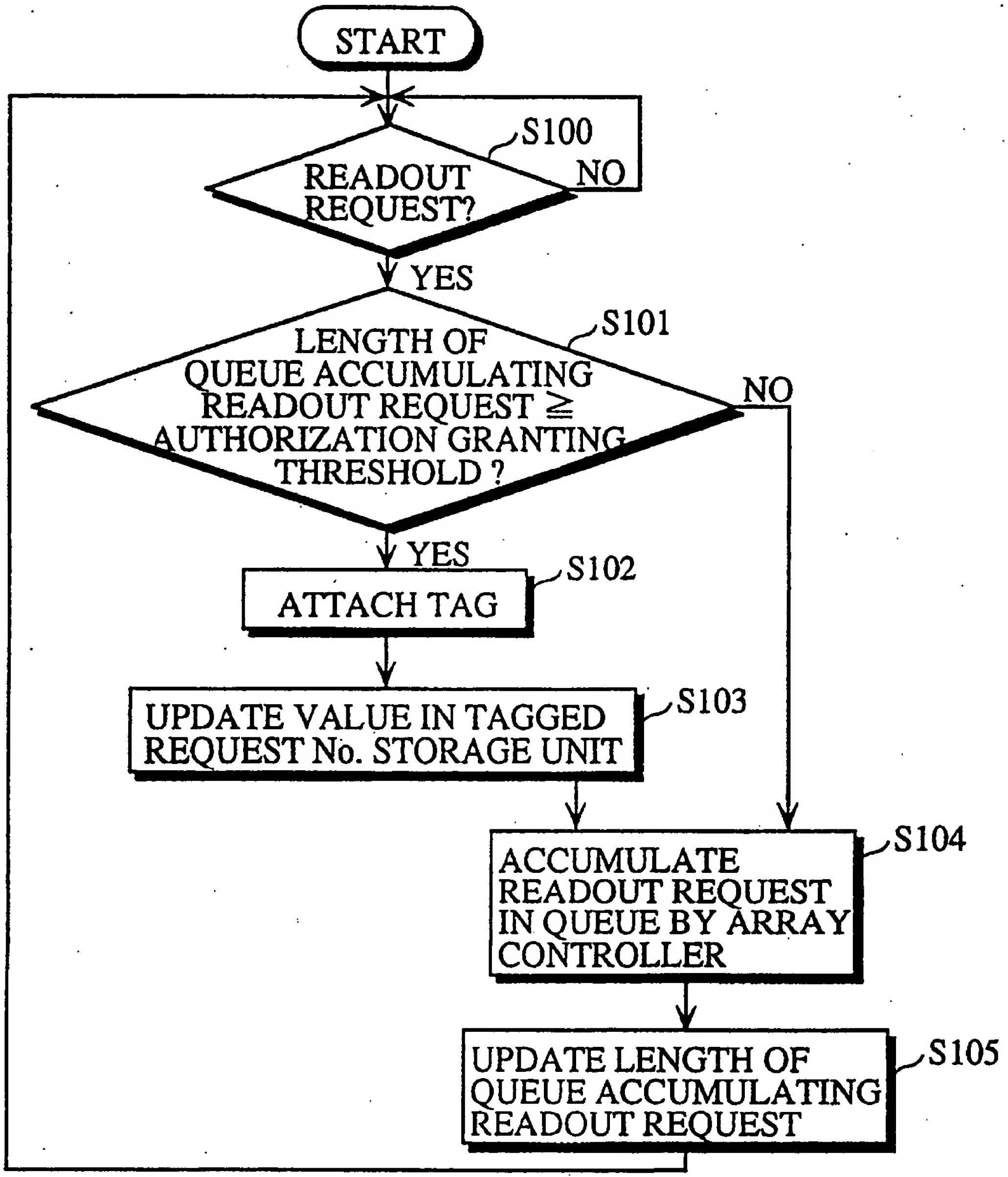

START
S100
READOUT REQUEST?
NO
YES
S101
LENGTH OF QUEUE ACCUMULATING READOUT REQUEST ≧ AUTHORIZATION GRANTING THRESHOLD ?
NO
YES
S102
ATTACH TAG
S103
UPDATE VALUE IN TAGGED REQUEST No. STORAGE UNIT
S104
ACCUMULATE READOUT REQUEST IN QUEUE BY ARRAY CONTROLLER
S105
UPDATE LENGTH OF QUEUE ACCUMULATING READOUT REQUEST

FIG. 35

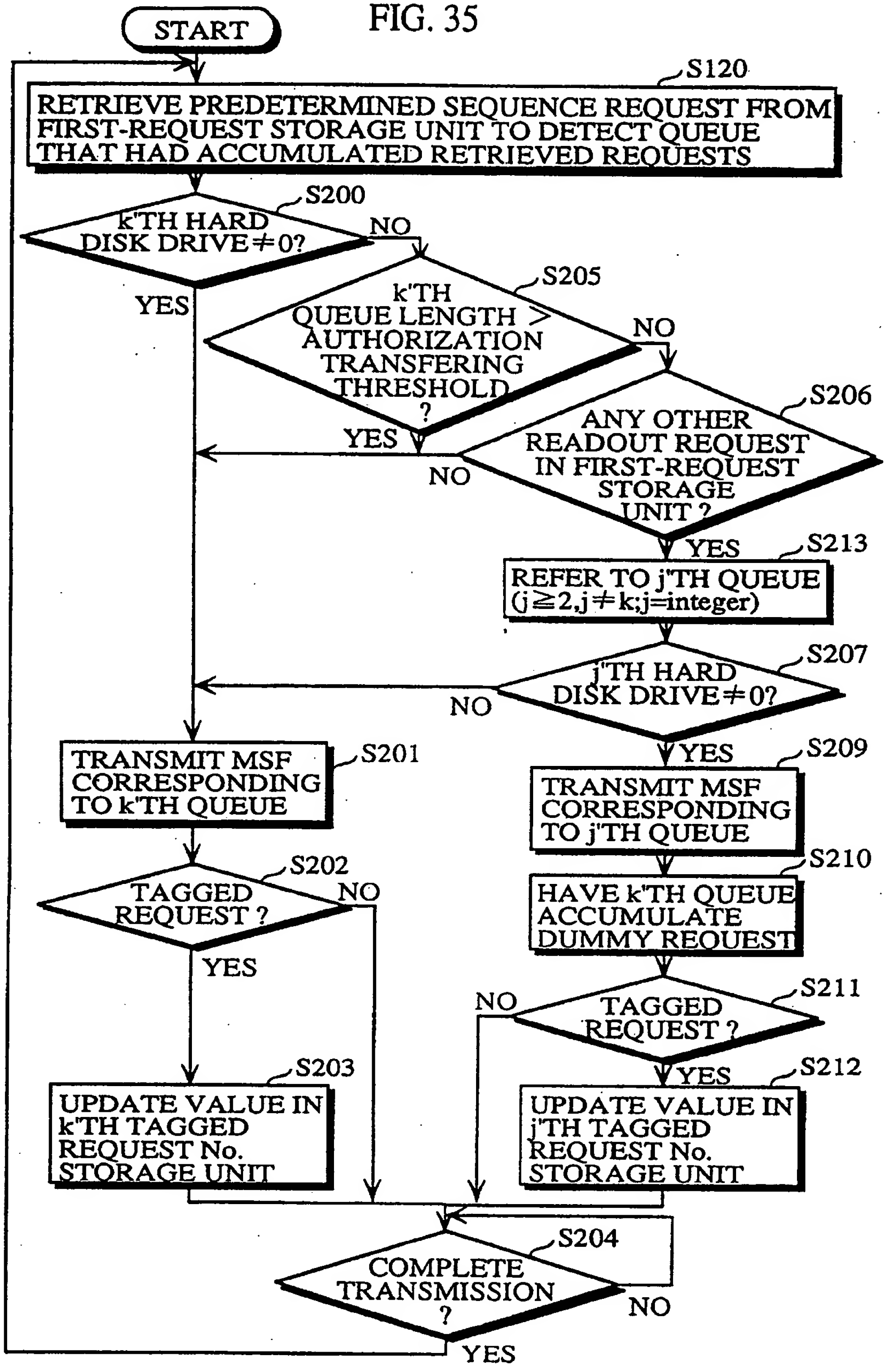

START
S120
RETRIEVE PREDETERMINED SEQUENCE REQUEST FROM FIRST-REQUEST STORAGE UNIT TO DETECT QUEUE THAT HAD ACCUMULATED RETRIEVED REQUESTS
S200
k'TH HARD DISK DRIVE ≠ 0?
NO
YES
S205
k'TH QUEUE LENGTH > AUTHORIZATION TRANSFERING THRESHOLD ?
NO
YES
S206
ANY OTHER READOUT REQUEST IN FIRST-REQUEST STORAGE UNIT ?
NO
YES
S213
REFER TO j'TH QUEUE (j≧2, j≠k; j=integer)
S207
j'TH HARD DISK DRIVE ≠ 0?
NO
YES
S201
TRANSMIT MSF CORRESPONDING TO k'TH QUEUE
S209
TRANSMIT MSF CORRESPONDING TO j'TH QUEUE
S210
HAVE k'TH QUEUE ACCUMULATE DUMMY REQUEST
S202
TAGGED REQUEST ?
NO
YES
S211
TAGGED REQUEST ?
NO
YES
S203
UPDATE VALUE IN k'TH TAGGED REQUEST No. STORAGE UNIT
S212
UPDATE VALUE IN j'TH TAGGED REQUEST No. STORAGE UNIT
S204
COMPLETE TRANSMISSION ?
NO
YES

FIG. 36

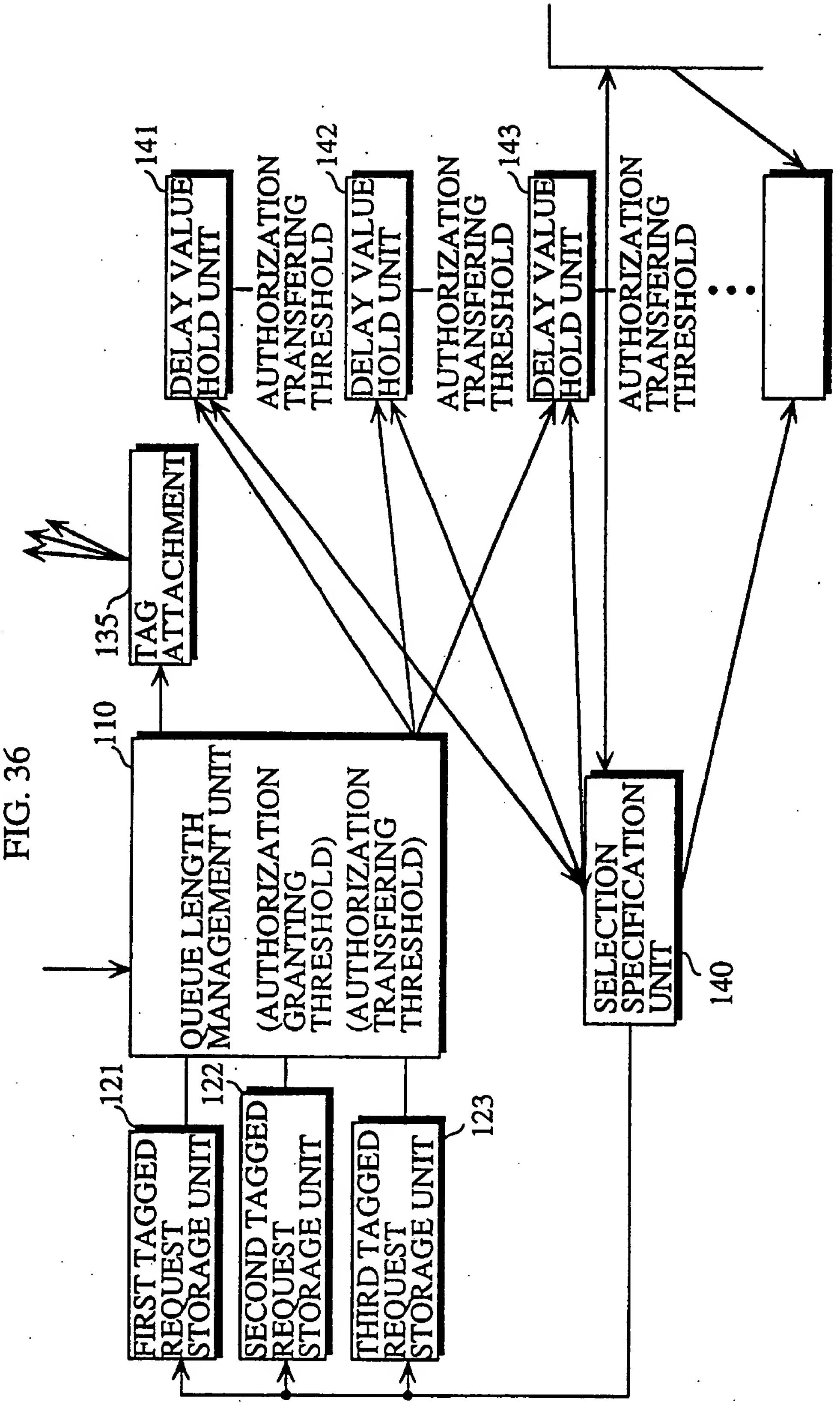

110
QUEUE LENGTH MANAGEMENT UNIT
(AUTHORIZATION GRANTING THRESHOLD)
(AUTHORIZATION TRANSFERING THRESHOLD)
135
TAG ATTACHMENT
121
FIRST TAGGED REQUEST STORAGE UNIT
122
SECOND TAGGED REQUEST STORAGE UNIT
123
THIRD TAGGED REQUEST STORAGE UNIT
141
DELAY VALUE HOLD UNIT
AUTHORIZATION TRANSFERING THRESHOLD
142
DELAY VALUE HOLD UNIT
AUTHORIZATION TRANSFERING THRESHOLD
143
DELAY VALUE HOLD UNIT
AUTHORIZATION TRANSFERING THRESHOLD
• • •
SELECTION SPECIFICATION UNIT
140

FIG. 37

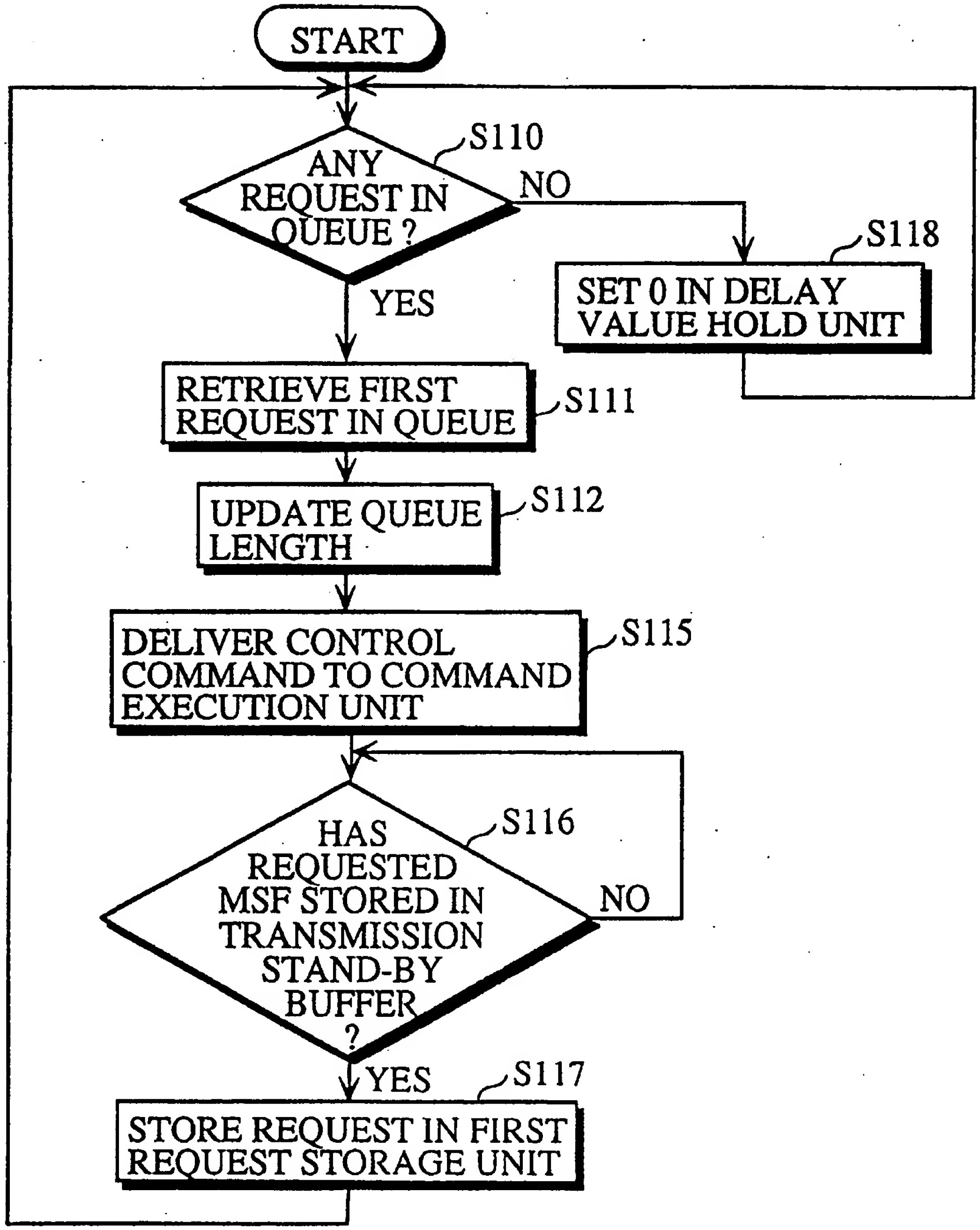

START
ANY REQUEST IN QUEUE ?
S110
NO
YES
SET 0 IN DELAY VALUE HOLD UNIT
S118
RETRIEVE FIRST REQUEST IN QUEUE
S111
UPDATE QUEUE LENGTH
S112
DELIVER CONTROL COMMAND TO COMMAND EXECUTION UNIT
S115
HAS REQUESTED MSF STORED IN TRANSMISSION STAND-BY BUFFER ?
S116
NO
YES
S117
STORE REQUEST IN FIRST REQUEST STORAGE UNIT

FIG. 38

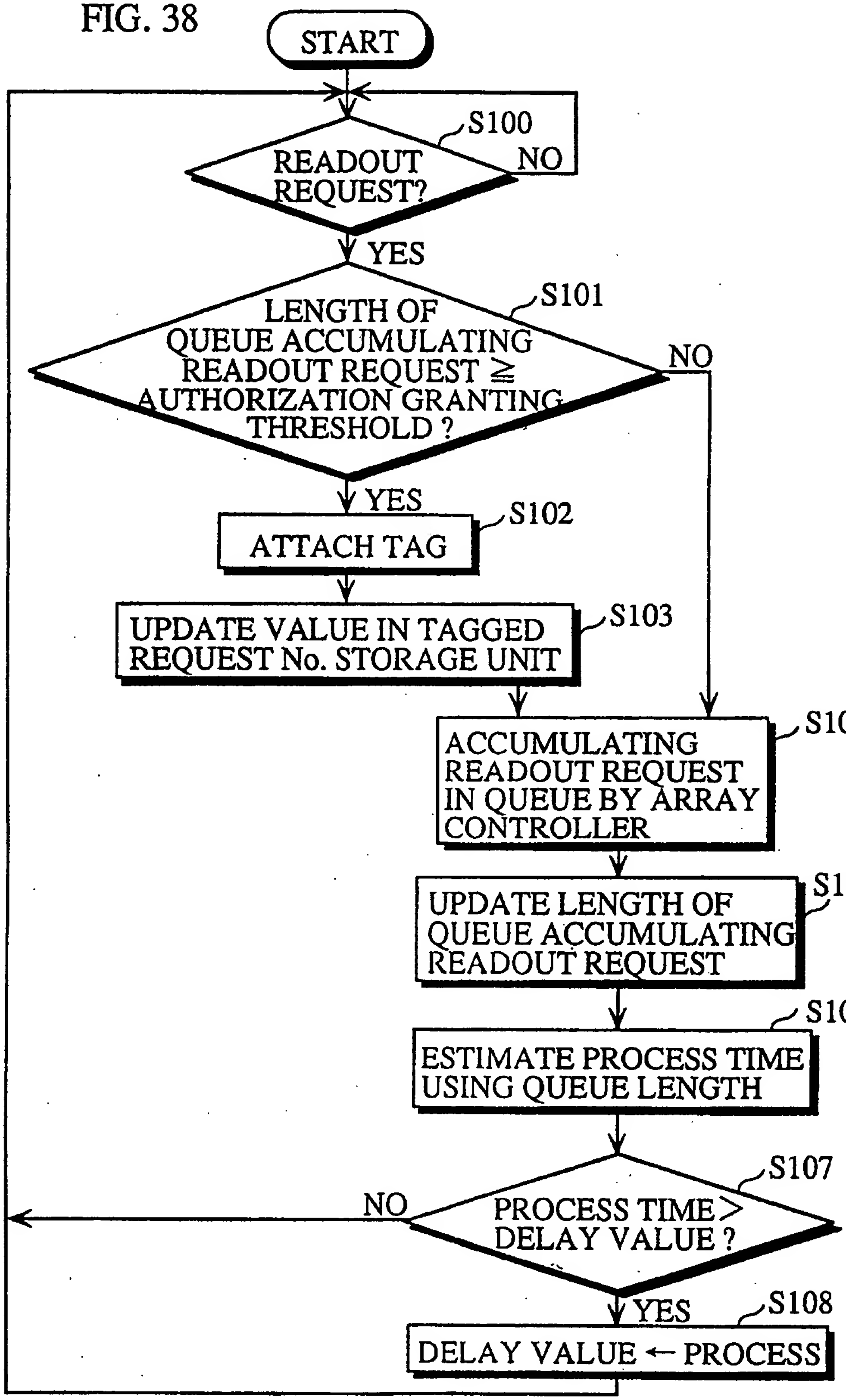

START
S100
READOUT REQUEST?
NO
YES
S101
LENGTH OF QUEUE ACCUMULATING READOUT REQUEST ≧ AUTHORIZATION GRANTING THRESHOLD ?
NO
YES
S102
ATTACH TAG
S103
UPDATE VALUE IN TAGGED REQUEST No. STORAGE UNIT
S104
ACCUMULATING READOUT REQUEST IN QUEUE BY ARRAY CONTROLLER
S105
UPDATE LENGTH OF QUEUE ACCUMULATING READOUT REQUEST
S106
ESTIMATE PROCESS TIME USING QUEUE LENGTH
S107
PROCESS TIME > DELAY VALUE ?
NO
YES
S108
DELAY VALUE ← PROCESS

FIG. 39

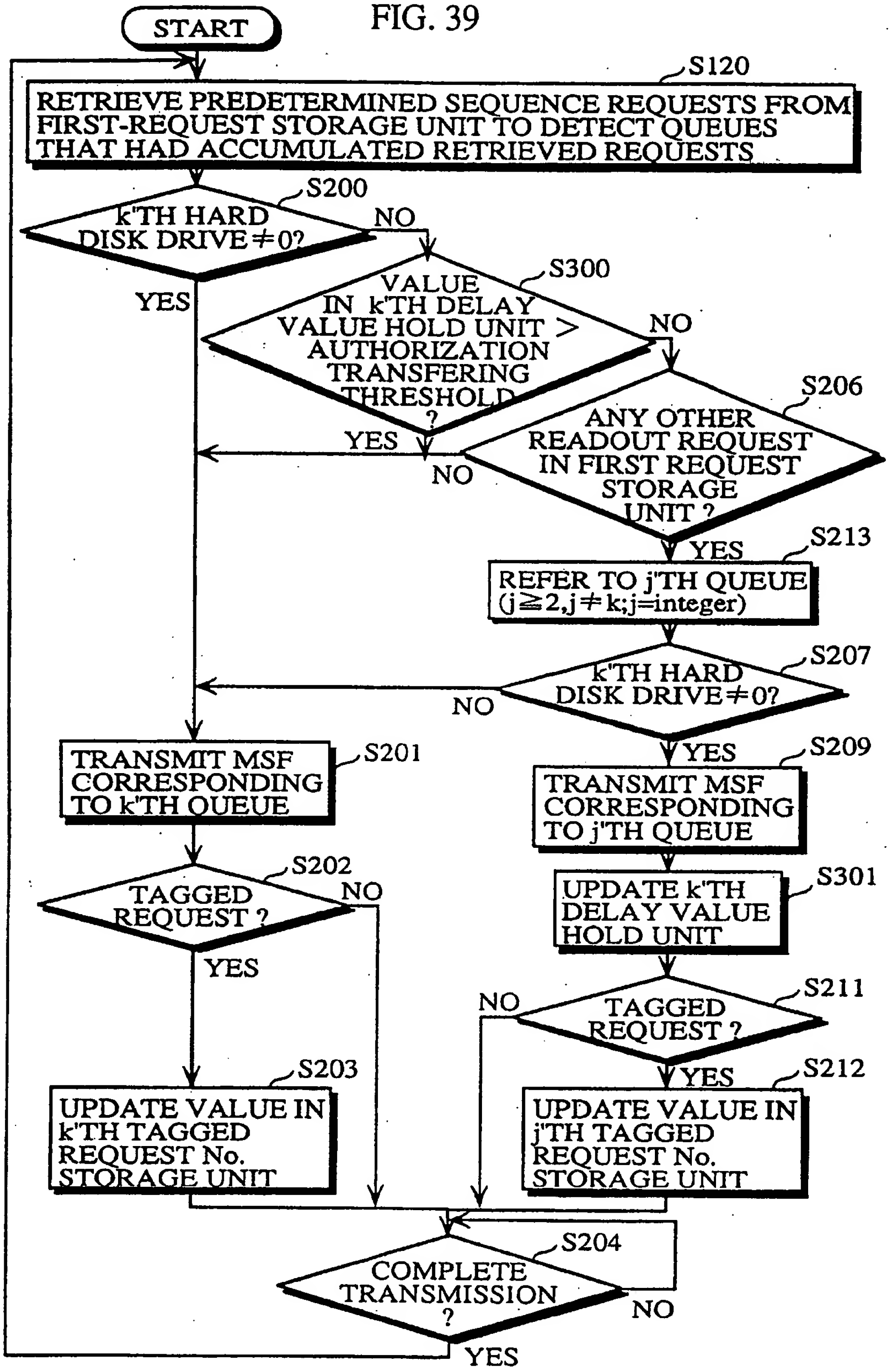

START
S120
RETRIEVE PREDETERMINED SEQUENCE REQUESTS FROM FIRST-REQUEST STORAGE UNIT TO DETECT QUEUES THAT HAD ACCUMULATED RETRIEVED REQUESTS
S200
k'TH HARD DISK DRIVE≠0?
NO
YES
S300
VALUE IN k'TH DELAY VALUE HOLD UNIT > AUTHORIZATION TRANSFERING THRESHOLD ?
NO
YES
S206
ANY OTHER READOUT REQUEST IN FIRST REQUEST STORAGE UNIT ?
NO
YES
S213
REFER TO j'TH QUEUE (j≧2,j≠k;j=integer)
S207
k'TH HARD DISK DRIVE≠0?
NO
YES
S201
TRANSMIT MSF CORRESPONDING TO k'TH QUEUE
S209
TRANSMIT MSF CORRESPONDING TO j'TH QUEUE
S301
UPDATE k'TH DELAY VALUE HOLD UNIT
S202
TAGGED REQUEST ?
NO
YES
S211
TAGGED REQUEST ?
NO
YES
S203
UPDATE VALUE IN k'TH TAGGED REQUEST No. STORAGE UNIT
S212
UPDATE VALUE IN j'TH TAGGED REQUEST No. STORAGE UNIT
S204
COMPLETE TRANSMISSION ?
NO
YES

FIG. 40

USR	INF	VAB	
TERMINAL'S ID	REQUESTED PROGRAM	MEAN RECEIPT RATE	

FIG. 41

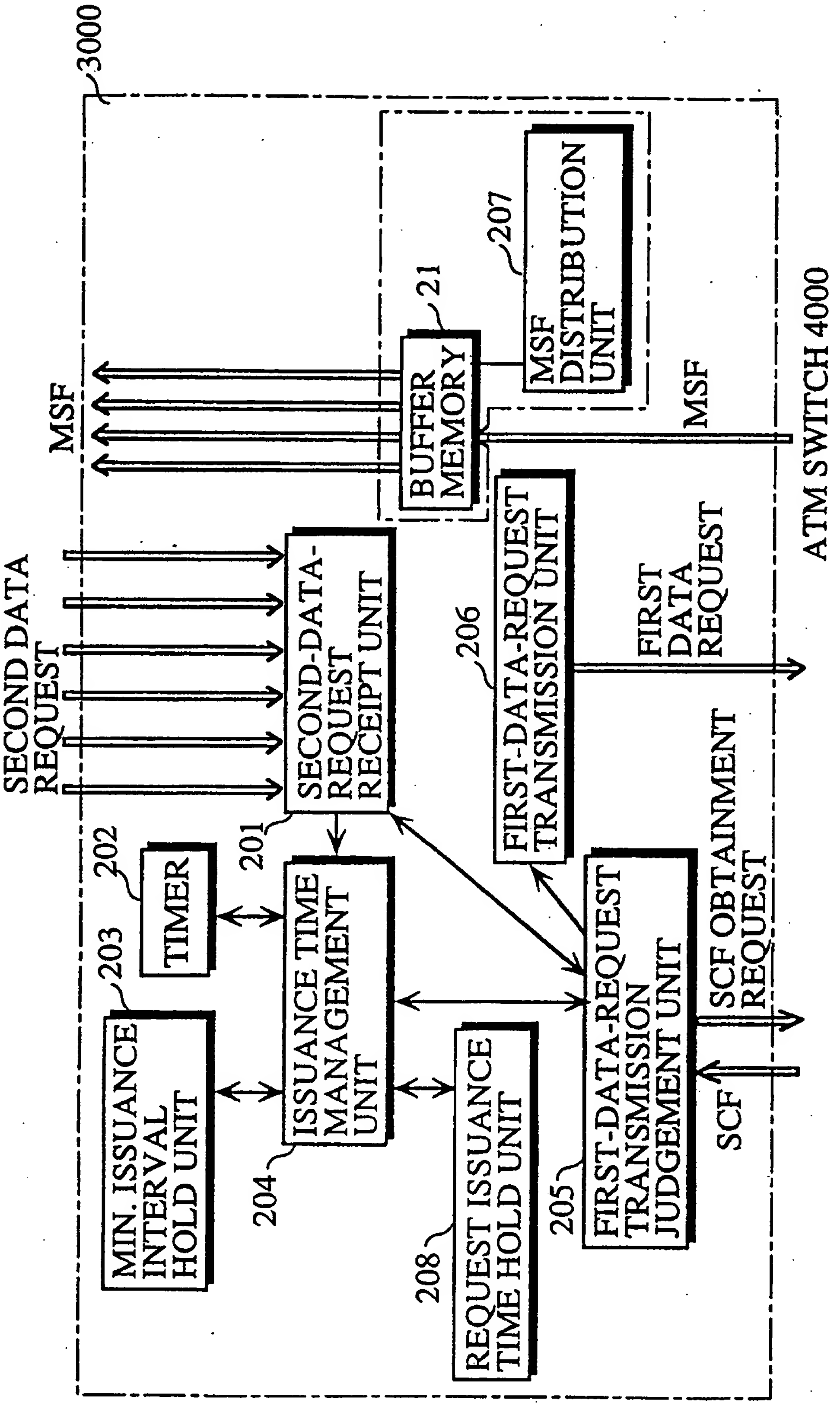

3000
SECOND DATA REQUEST
MSF
201
SECOND-DATA-REQUEST RECEIPT UNIT
21
BUFFER MEMORY
207
MSF DISTRIBUTION UNIT
MSF
ATM SWITCH 4000
202
TIMER
203
MIN. ISSUANCE INTERVAL HOLD UNIT
204
ISSUANCE TIME MANAGEMENT UNIT
208
REQUEST ISSUANCE TIME HOLD UNIT
206
FIRST-DATA-REQUEST TRANSMISSION UNIT
FIRST DATA REQUEST
205
FIRST-DATA-REQUEST TRANSMISSION JUDGEMENT UNIT
SCF OBTAINMENT REQUEST
SCF

FIG. 42

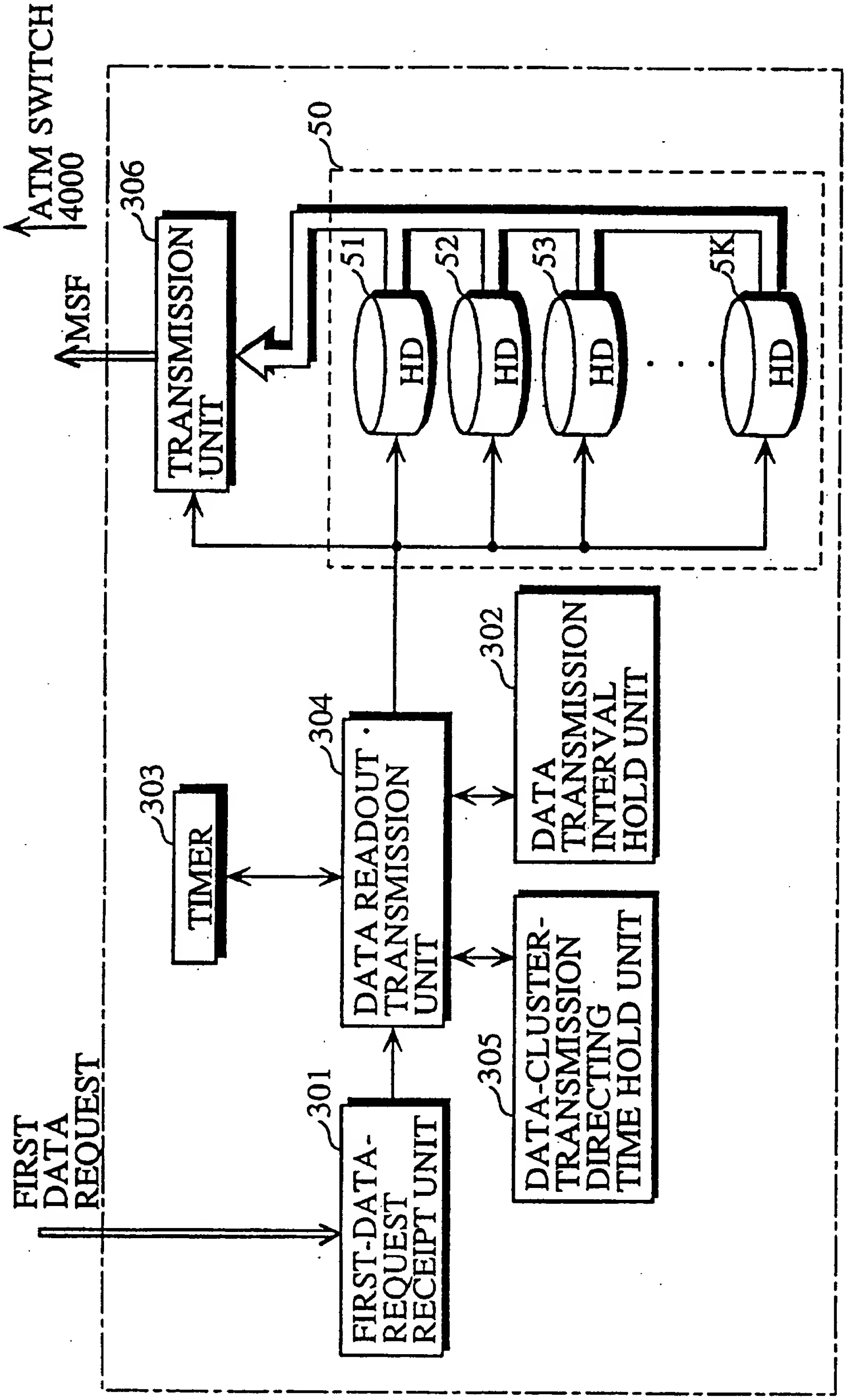

ATM SWITCH
4000
MSF
306
TRANSMISSION UNIT
50
51
52
53
5K
HD
HD
HD
HD
FIRST DATA REQUEST
301
FIRST-DATA-REQUEST RECEIPT UNIT
303
TIMER
304
DATA READOUT · TRANSMISSION UNIT
302
DATA TRANSMISSION INTERVAL HOLD UNIT
305
DATA-CLUSTER-TRANSMISSION DIRECTING TIME HOLD UNIT

FIG. 43

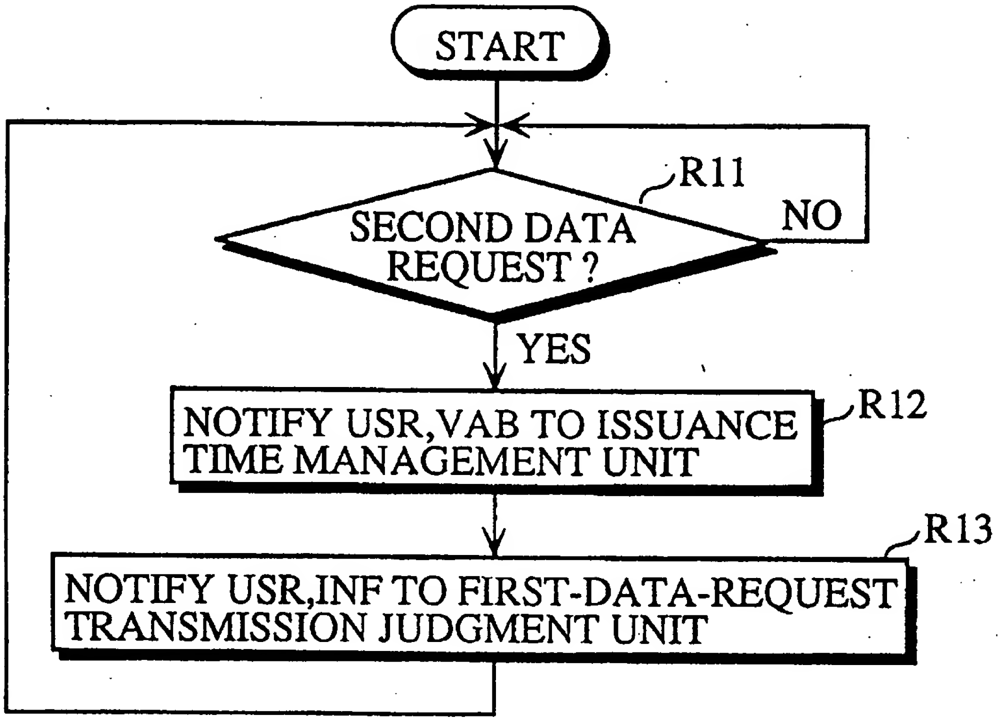
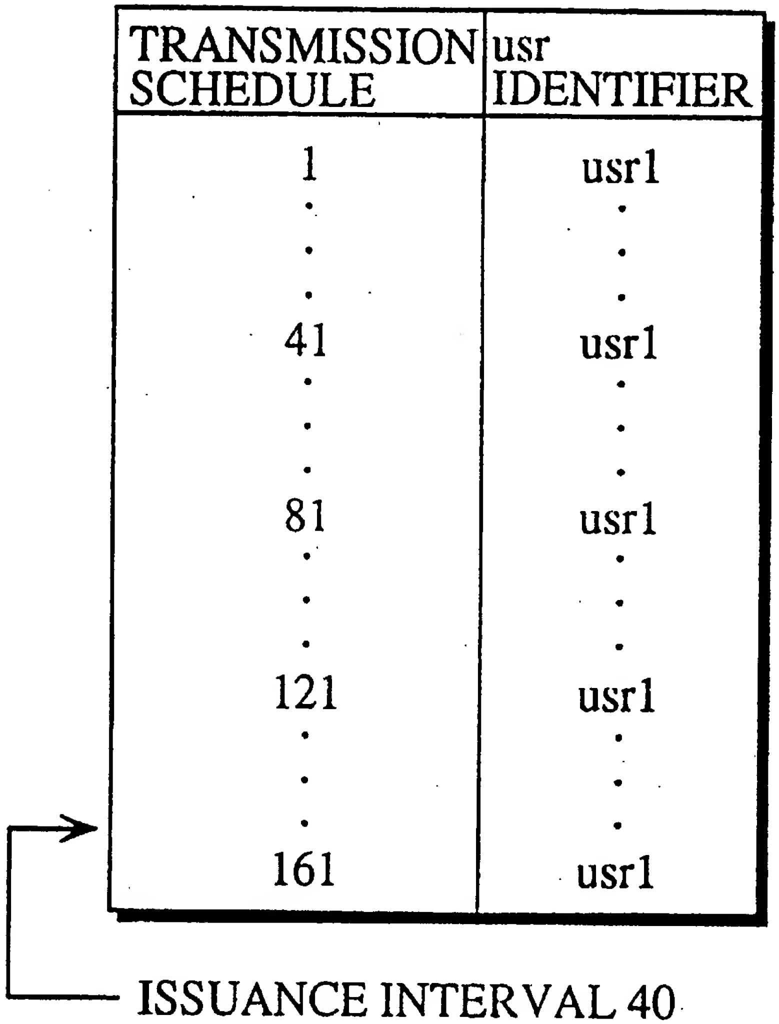

START
SECOND DATA REQUEST ?
R11
NO
YES
NOTIFY USR,VAB TO ISSUANCE TIME MANAGEMENT UNIT
R12
R13
NOTIFY USR,INF TO FIRST-DATA-REQUEST TRANSMISSION JUDGMENT UNIT

FIG. 44

USR	ADD
TERMINAL'S ID	SCF(MSFPs)

FIG. 45A



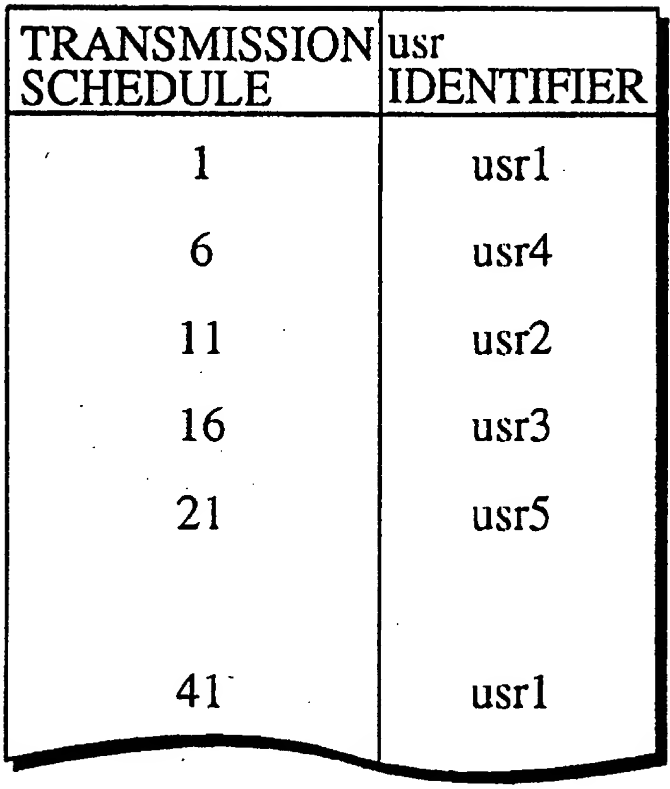
TRANSMISSION SCHEDULE	usr IDENTIFIER
1	usr1
⋮	⋮
41	usr1
⋮	⋮
81	usr1
⋮	⋮
121	usr1
⋮	⋮
161	usr1

ISSUANCE INTERVAL 40

FIG. 45B

TRANSMISSION SCHEDULE	usr IDENTIFIER
1	usr1
.	.
.	.
6	usr4
.	.
.	.
41	usr1
.	.
.	.
46	usr4
.	.
.	.
81	usr1
.	.
.	.
86	usr4
.	.
.	.
121	usr1
.	.
.	.
126	usr4

FIG. 45C



TRANSMISSION SCHEDULE	usr IDENTIFIER
1	usr1
6	usr4
11	usr2
16	usr3
21	usr5
41	usr1

FIG. 46

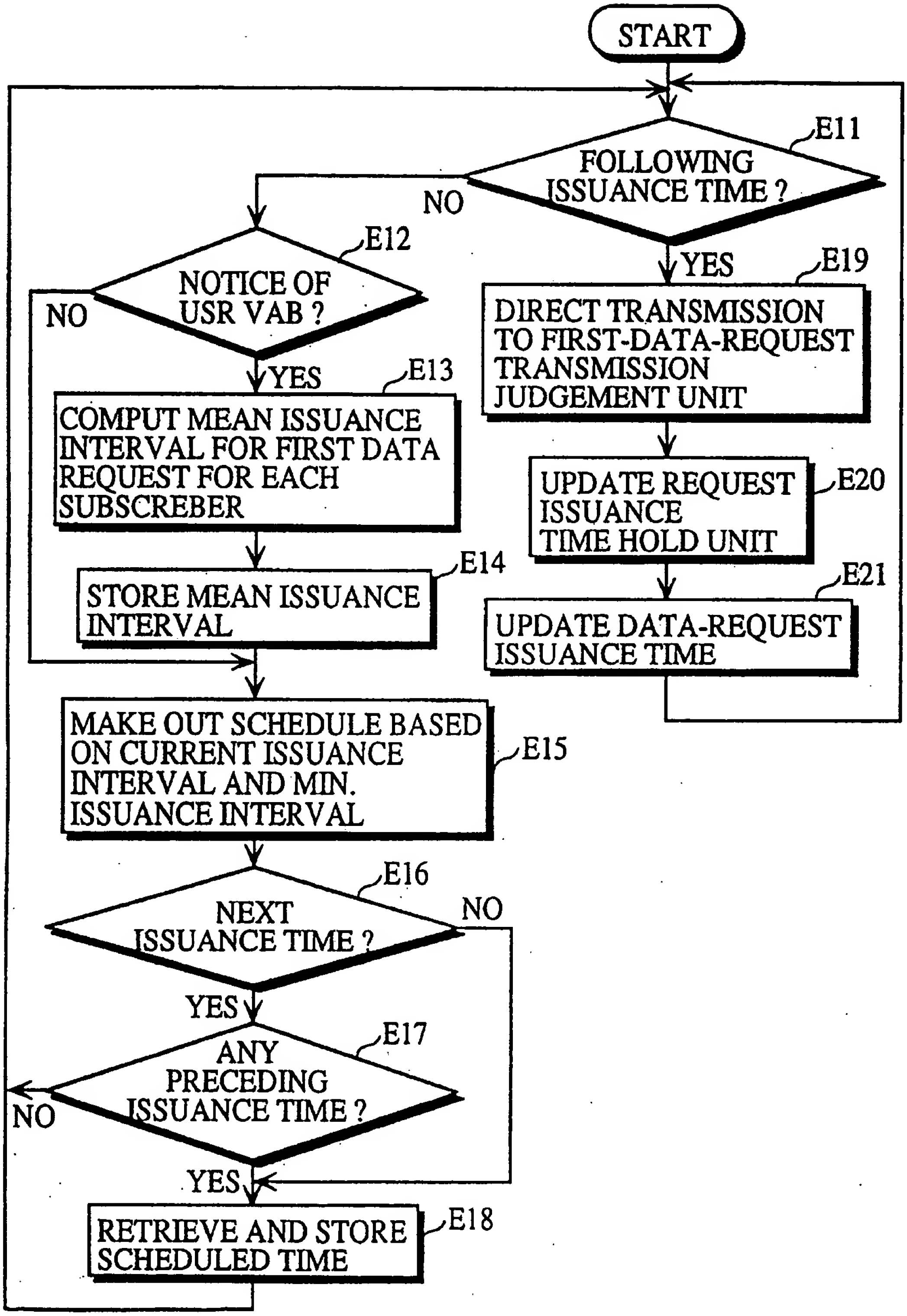

START
FOLLOWING ISSUANCE TIME ?
E11
NO
YES
NOTICE OF USR VAB ?
E12
NO
YES
COMPUT MEAN ISSUANCE INTERVAL FOR FIRST DATA REQUEST FOR EACH SUBSCREBER
E13
STORE MEAN ISSUANCE INTERVAL
E14
MAKE OUT SCHEDULE BASED ON CURRENT ISSUANCE INTERVAL AND MIN. ISSUANCE INTERVAL
E15
NEXT ISSUANCE TIME ?
E16
NO
YES
ANY PRECEDING ISSUANCE TIME ?
E17
NO
YES
RETRIEVE AND STORE SCHEDULED TIME
E18
DIRECT TRANSMISSION TO FIRST-DATA-REQUEST TRANSMISSION JUDGEMENT UNIT
E19
UPDATE REQUEST ISSUANCE TIME HOLD UNIT
E20
UPDATE DATA-REQUEST ISSUANCE TIME
E21

FIG. 47

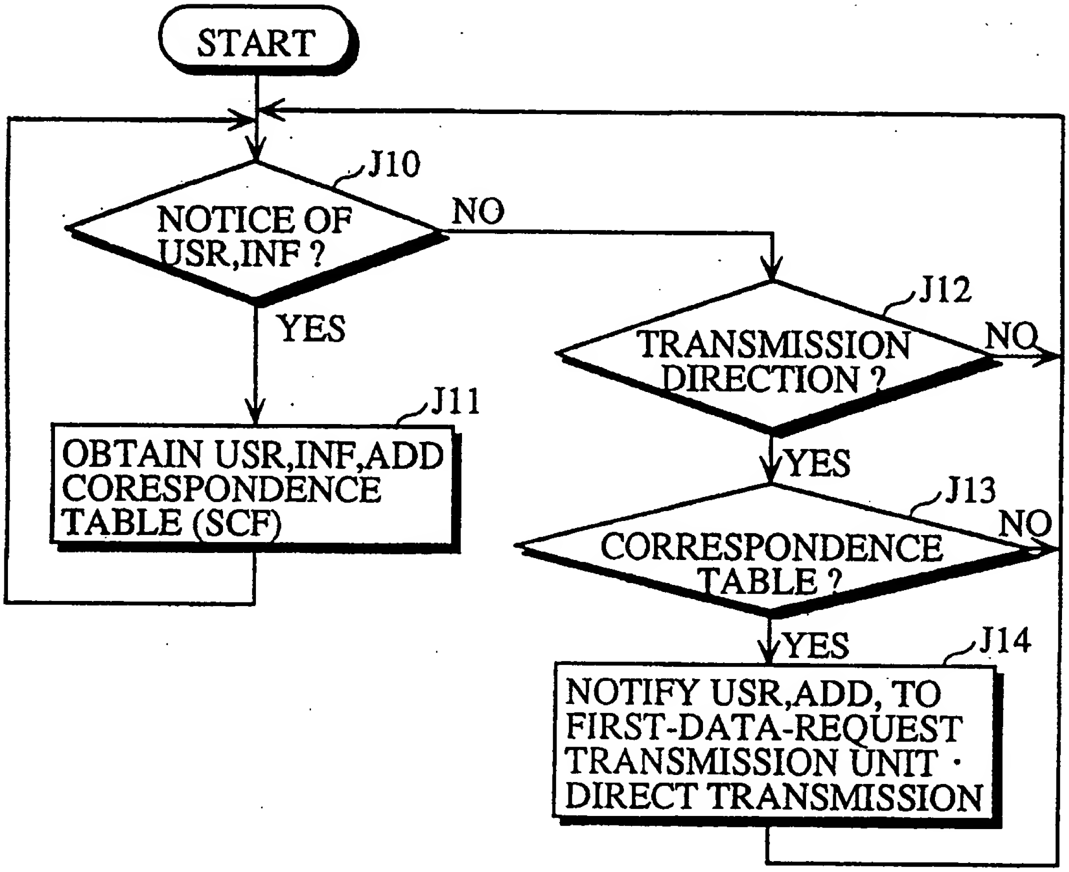

START
J10
NOTICE OF USR,INF ?
NO
YES
J11
OBTAIN USR,INF,ADD CORESPONDENCE TABLE (SCF)
J12
TRANSMISSION DIRECTION ?
NO
YES
J13
CORRESPONDENCE TABLE ?
NO
YES
J14
NOTIFY USR,ADD, TO FIRST-DATA-REQUEST TRANSMISSION UNIT · DIRECT TRANSMISSION

FIG. 48

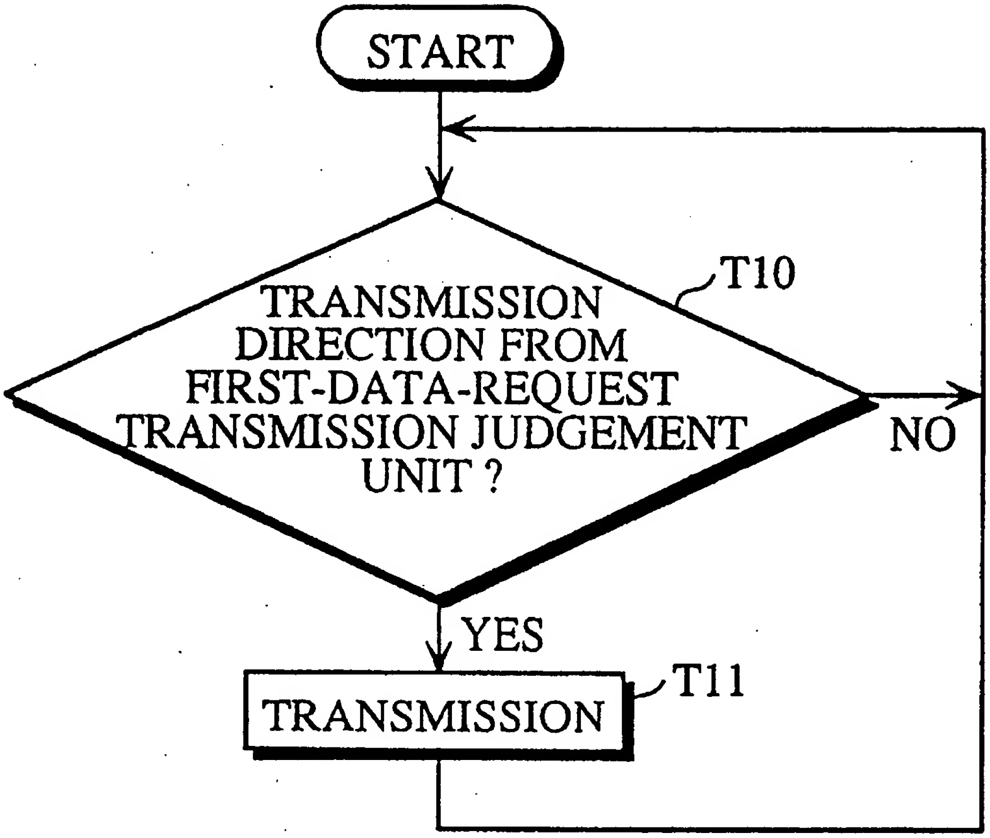

START
TRANSMISSION DIRECTION FROM FIRST-DATA-REQUEST TRANSMISSION JUDGEMENT UNIT ?
T10
NO
YES
TRANSMISSION
T11

FIG. 49A

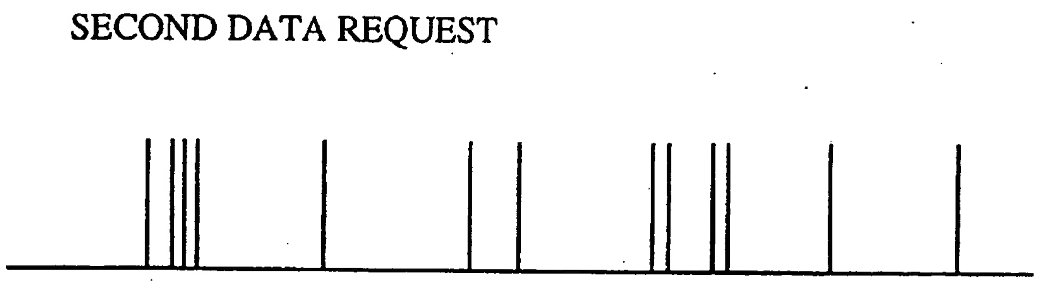


FIG. 49B

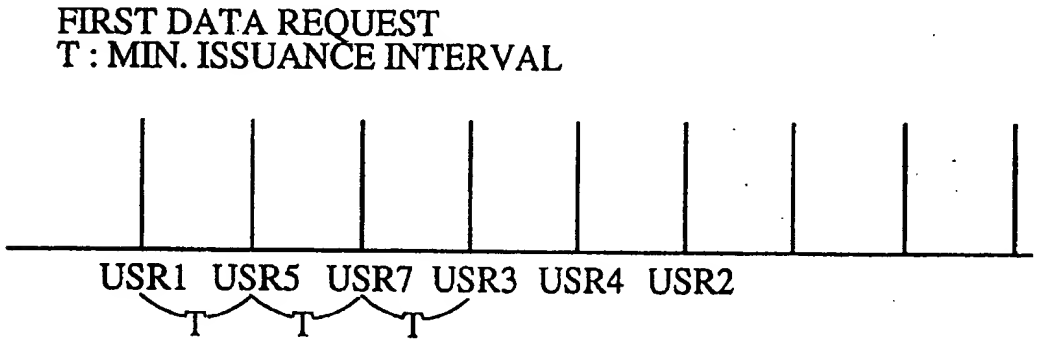


FIG. 50

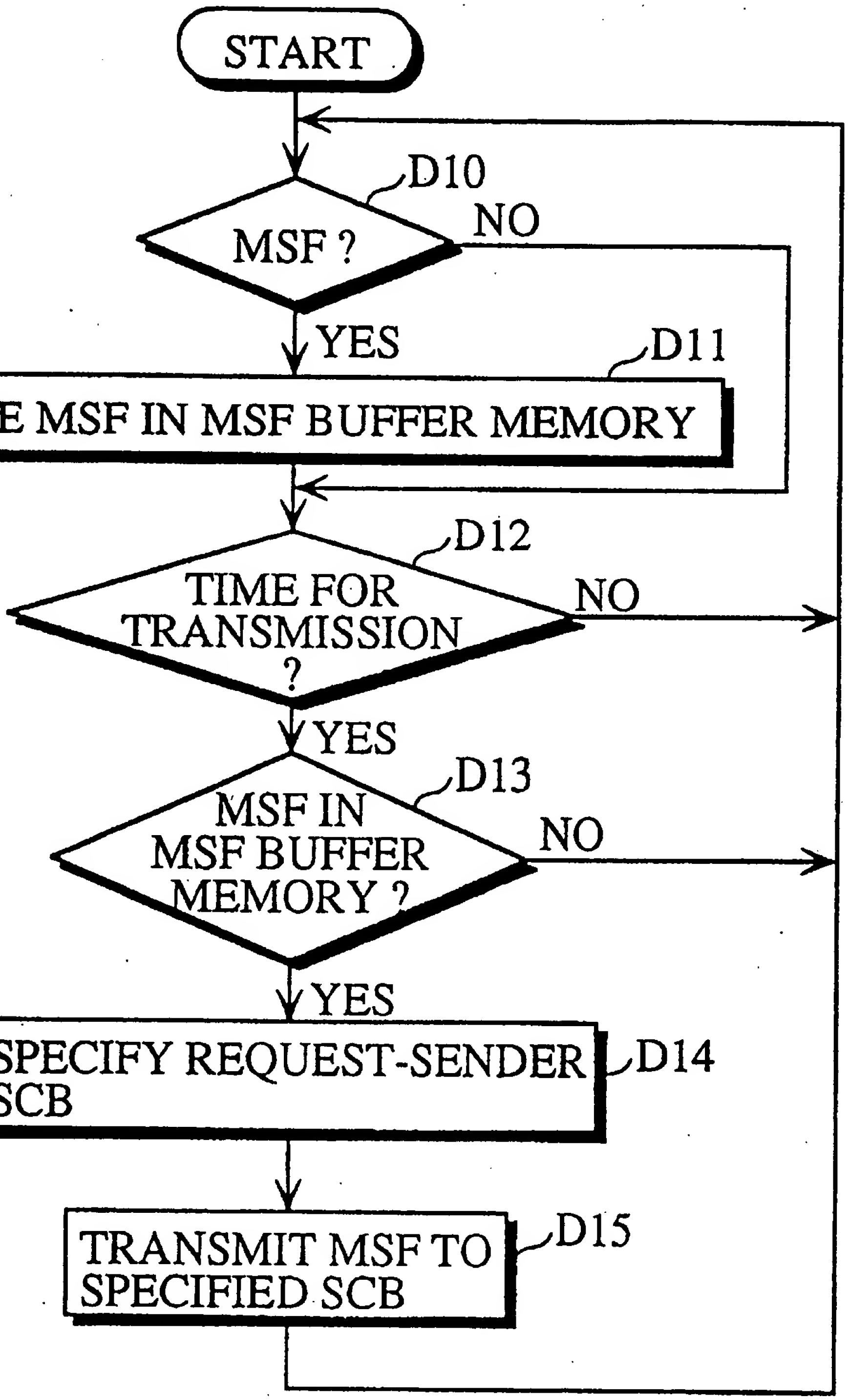

START
D10
MSF ?
NO
YES
D11
STORE MSF IN MSF BUFFER MEMORY
D12
TIME FOR TRANSMISSION ?
NO
YES
D13
MSF IN MSF BUFFER MEMORY ?
NO
YES
SPECIFY REQUEST-SENDER SCB
D14
TRANSMIT MSF TO SPECIFIED SCB
D15

FIG. 51

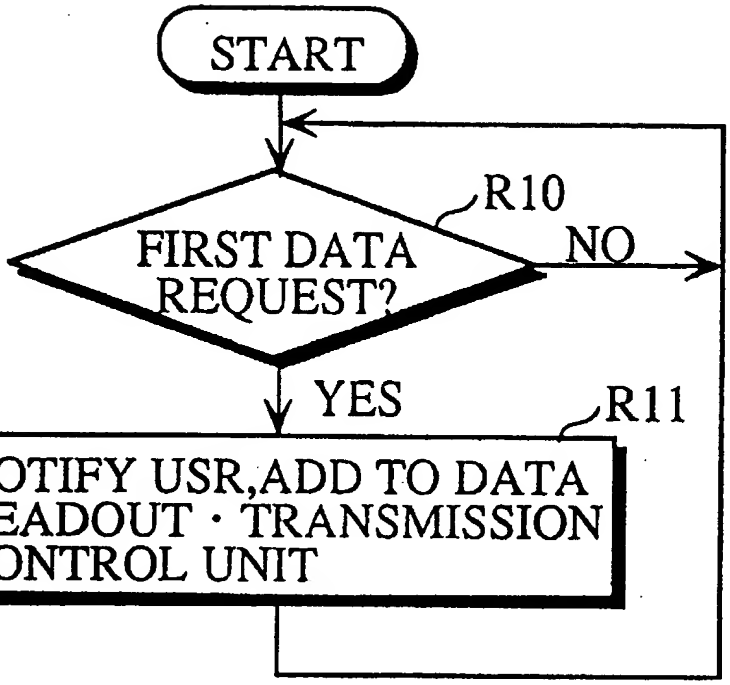

START
FIRST DATA REQUEST?
R10
NO
YES
R11
NOTIFY USR,ADD TO DATA READOUT · TRANSMISSION CONTROL UNIT

FIG. 52

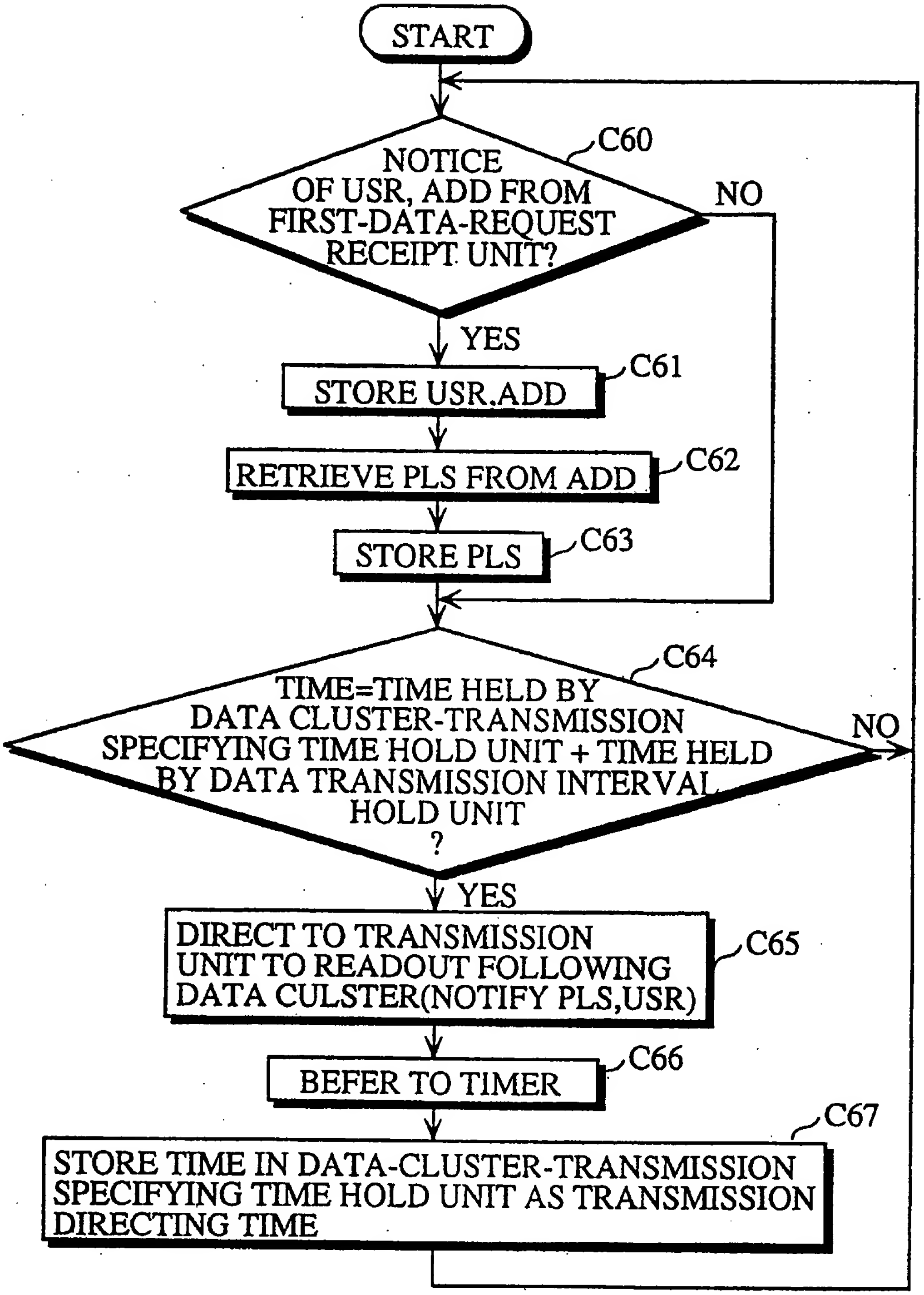

START
NOTICE OF USR, ADD FROM FIRST-DATA-REQUEST RECEIPT UNIT?
C60
NO
YES
STORE USR.ADD
C61
RETRIEVE PLS FROM ADD
C62
STORE PLS
C63
TIME=TIME HELD BY DATA CLUSTER-TRANSMISSION SPECIFYING TIME HOLD UNIT + TIME HELD BY DATA TRANSMISSION INTERVAL HOLD UNIT ?
C64
NO
YES
DIRECT TO TRANSMISSION UNIT TO READOUT FOLLOWING DATA CULSTER(NOTIFY PLS,USR)
C65
BEFER TO TIMER
C66
STORE TIME IN DATA-CLUSTER-TRANSMISSION SPECIFYING TIME HOLD UNIT AS TRANSMISSION DIRECTING TIME
C67

FIG. 53

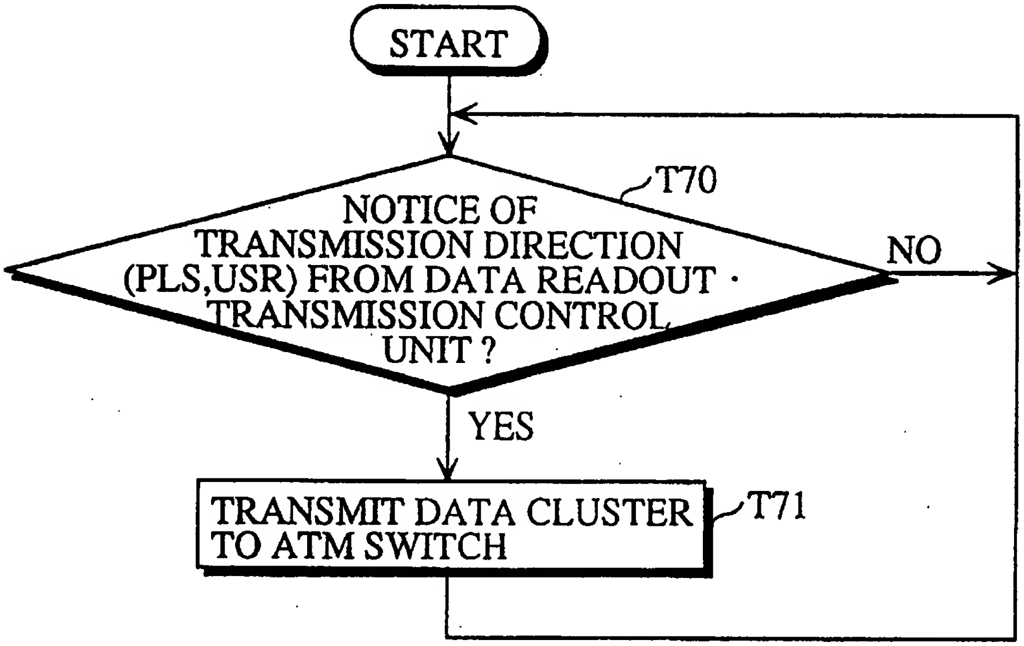

START
NOTICE OF TRANSMISSION DIRECTION (PLS,USR) FROM DATA READOUT · TRANSMISSION CONTROL UNIT ?
T70
NO
YES
TRANSMIT DATA CLUSTER TO ATM SWITCH
T71

FIG. 54

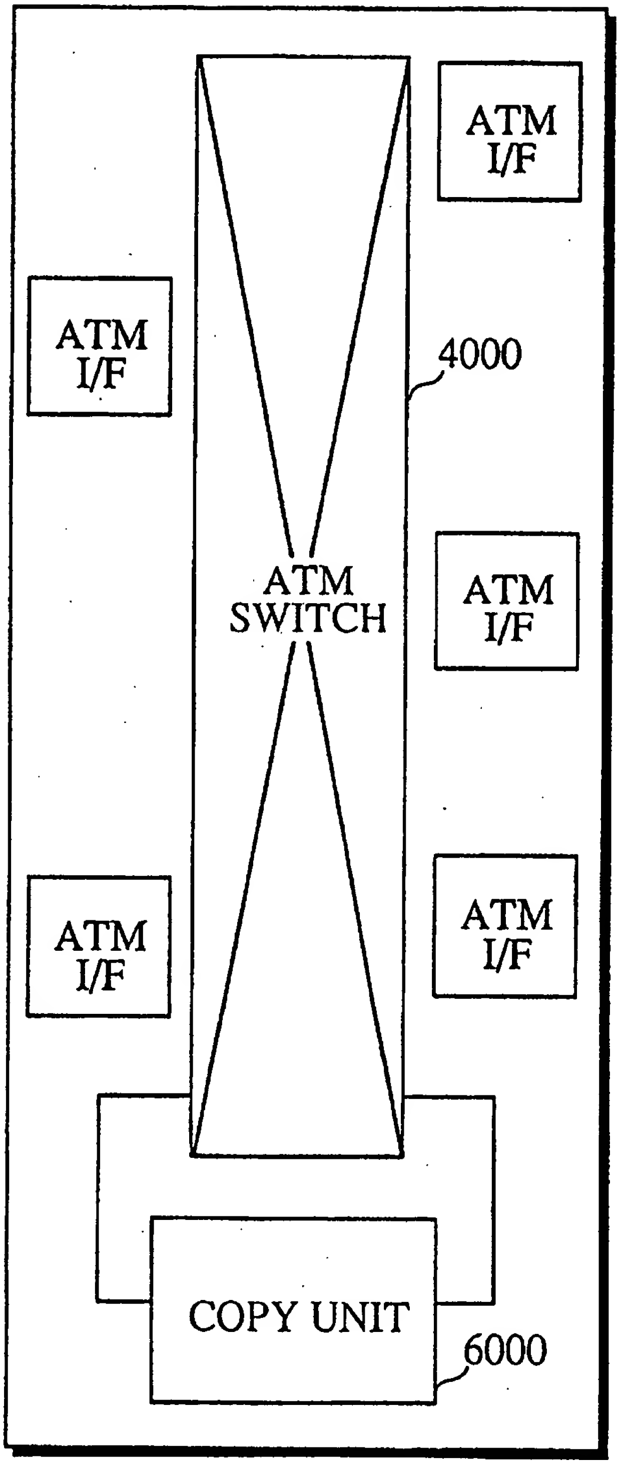

ATM I/F
ATM I/F
4000
ATM SWITCH
ATM I/F
ATM I/F
ATM I/F
COPY UNIT
6000

FIG. 55

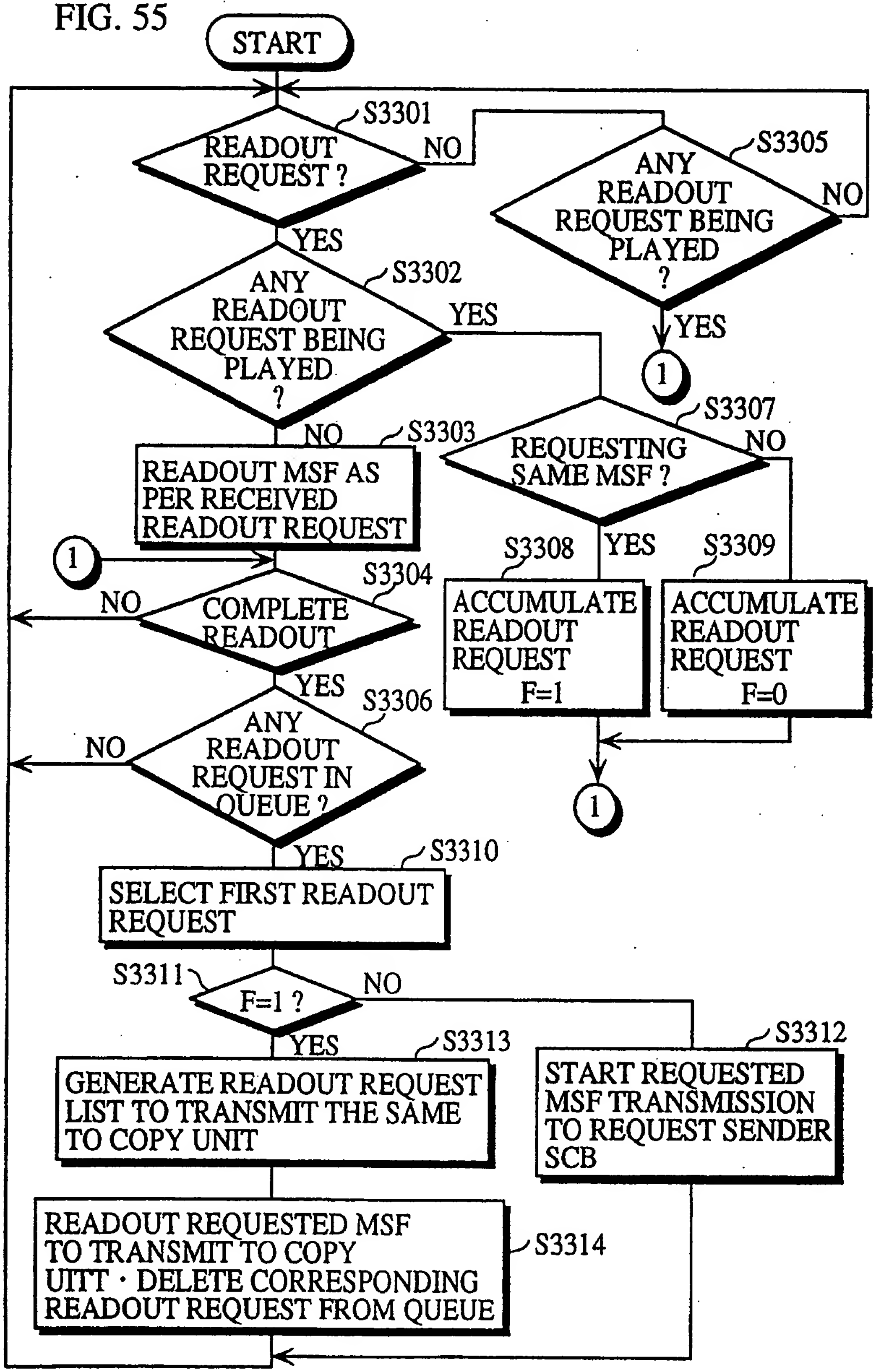

START
S3301
READOUT REQUEST ?
NO
YES
S3305
ANY READOUT REQUEST BEING PLAYED ?
NO
YES
1
S3302
ANY READOUT REQUEST BEING PLAYED ?
YES
NO
S3303
READOUT MSF AS PER RECEIVED READOUT REQUEST
S3307
REQUESTING SAME MSF ?
NO
YES
1
S3304
COMPLETE READOUT
NO
YES
S3308
ACCUMULATE READOUT REQUEST F=1
S3309
ACCUMULATE READOUT REQUEST F=0
S3306
ANY READOUT REQUEST IN QUEUE ?
NO
YES
1
S3310
SELECT FIRST READOUT REQUEST
S3311
F=1 ?
NO
YES
S3313
GENERATE READOUT REQUEST LIST TO TRANSMIT THE SAME TO COPY UNIT
S3312
START REQUESTED MSF TRANSMISSION TO REQUEST SENDER SCB
READOUT REQUESTED MSF TO TRANSMIT TO COPY UITT · DELETE CORRESPONDING READOUT REQUEST FROM QUEUE
S3314

FIG. 56

MSF TRANSMISSION
MANAGEMENT TABLE

REQUESTED MSF IDENTIFICATION No.	DESTINATION	OTHER DESTINATION LIST
2130	1	10
6521	2	1,3
7651	3	
123	1	
● ● ●	● ● ●	● ● ●

FIG. 57

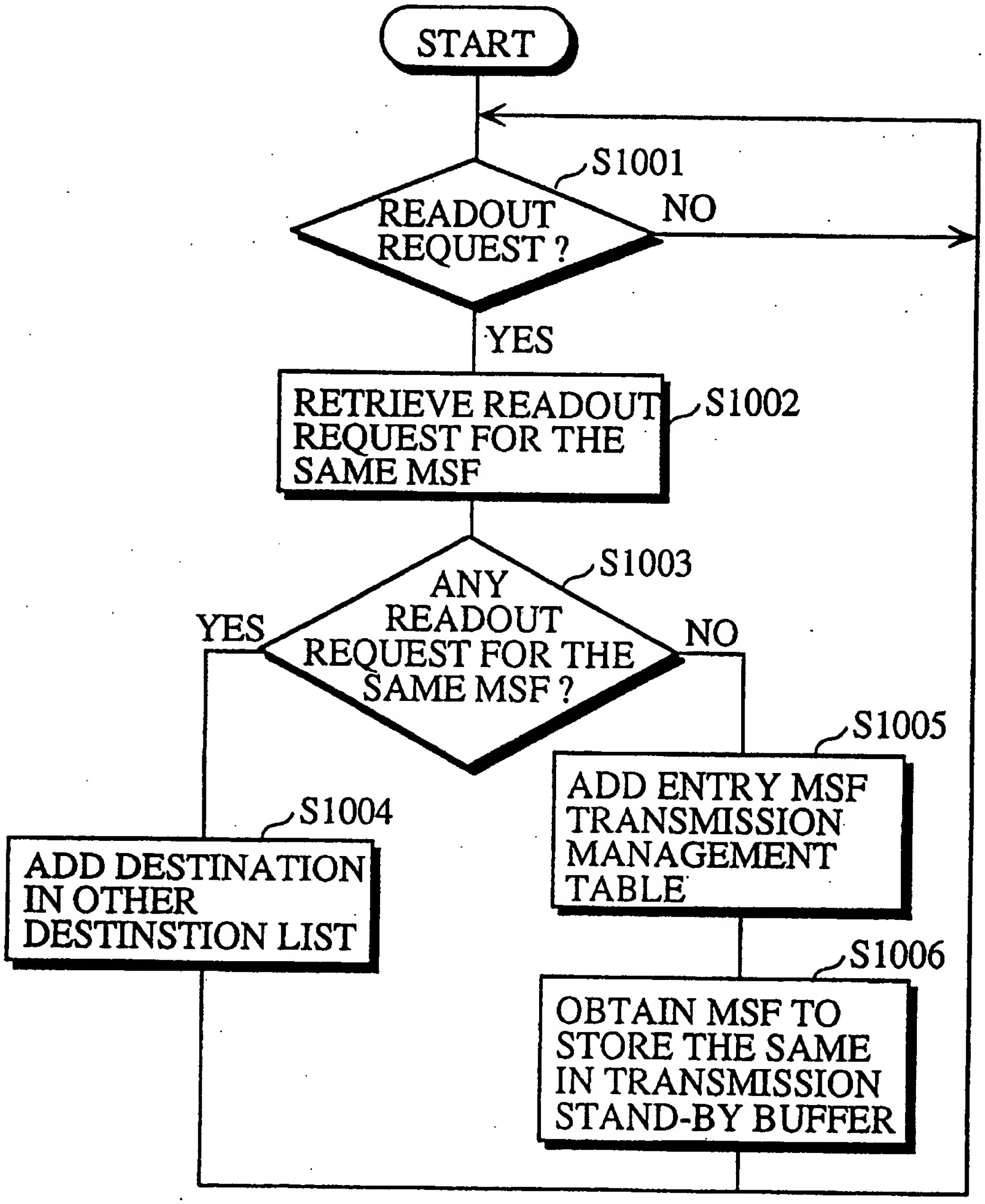

START
S1001
READOUT REQUEST ?
NO
YES
RETRIEVE READOUT REQUEST FOR THE SAME MSF
S1002
S1003
ANY READOUT REQUEST FOR THE SAME MSF ?
YES
NO
S1005
ADD ENTRY MSF TRANSMISSION MANAGEMENT TABLE
S1004
ADD DESTINATION IN OTHER DESTINSTION LIST
S1006
OBTAIN MSF TO STORE THE SAME IN TRANSMISSION STAND-BY BUFFER

FIG. 58

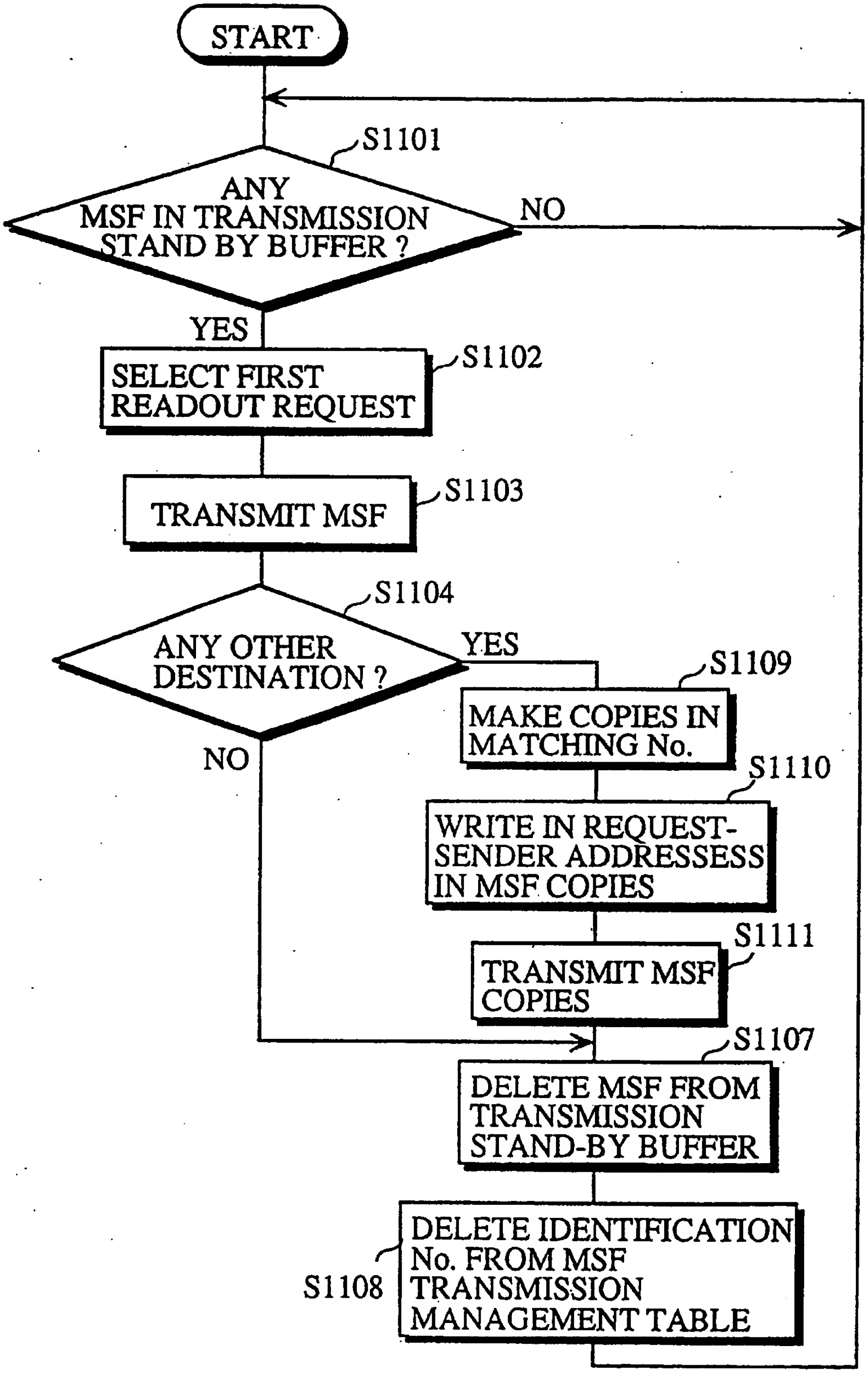

START
S1101
ANY MSF IN TRANSMISSION STAND BY BUFFER ?
NO
YES
SELECT FIRST READOUT REQUEST
S1102
TRANSMIT MSF
S1103
S1104
ANY OTHER DESTINATION ?
YES
NO
S1109
MAKE COPIES IN MATCHING No.
S1110
WRITE IN REQUEST-SENDER ADDRESSESS IN MSF COPIES
S1111
TRANSMIT MSF COPIES
S1107
DELETE MSF FROM TRANSMISSION STAND-BY BUFFER
S1108
DELETE IDENTIFICATION No. FROM MSF TRANSMISSION MANAGEMENT TABLE

FIG. 59

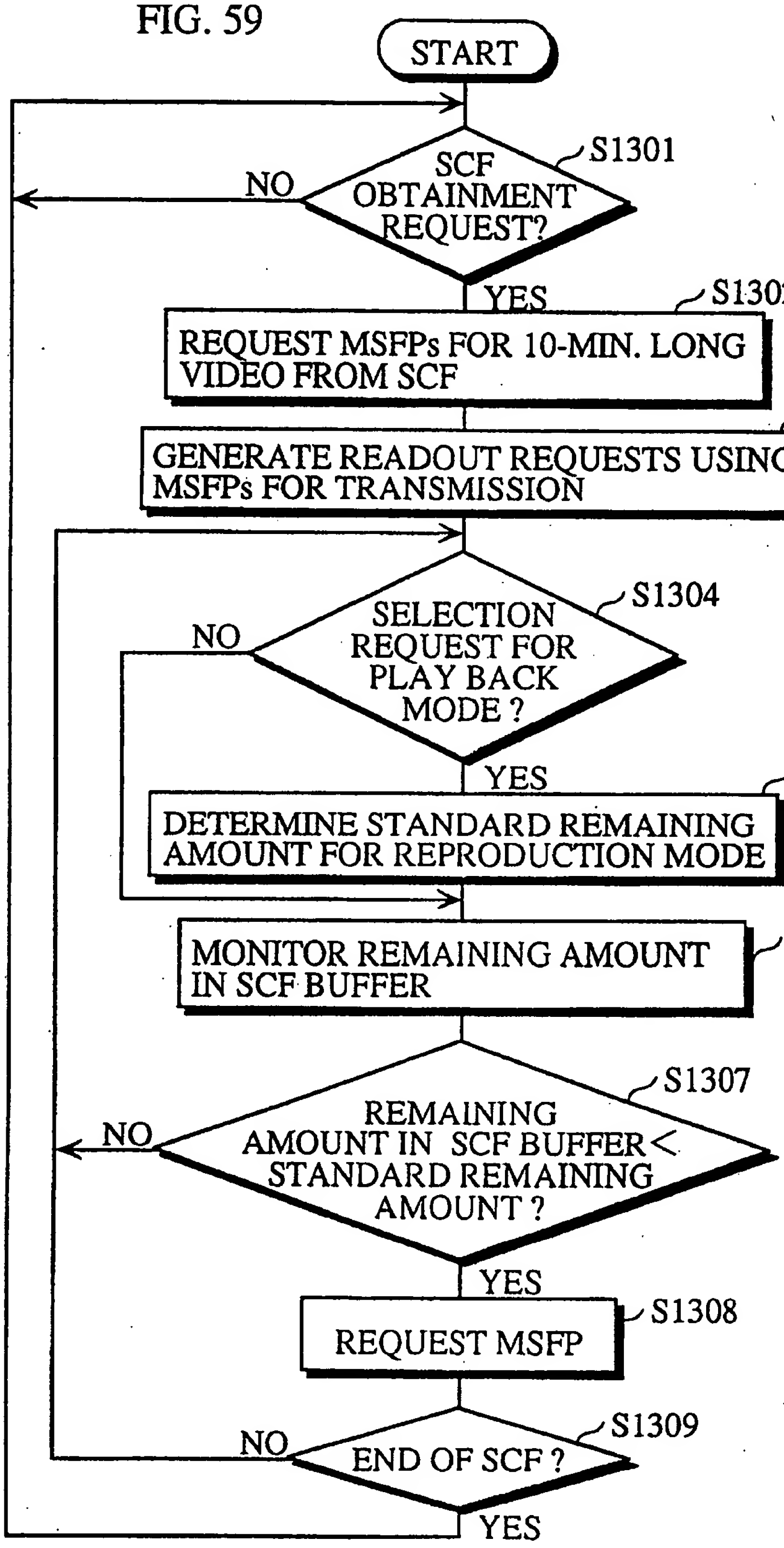

START
SCF OBTAINMENT REQUEST?
S1301
NO
YES
REQUEST MSFPs FOR 10-MIN. LONG VIDEO FROM SCF
S1302
GENERATE READOUT REQUESTS USING MSFPs FOR TRANSMISSION
S1303
SELECTION REQUEST FOR PLAY BACK MODE ?
S1304
NO
YES
DETERMINE STANDARD REMAINING AMOUNT FOR REPRODUCTION MODE
S1305
MONITOR REMAINING AMOUNT IN SCF BUFFER
S1306
REMAINING AMOUNT IN SCF BUFFER < STANDARD REMAINING AMOUNT ?
S1307
NO
YES
REQUEST MSFP
S1308
END OF SCF ?
S1309
NO
YES

FIG. 60

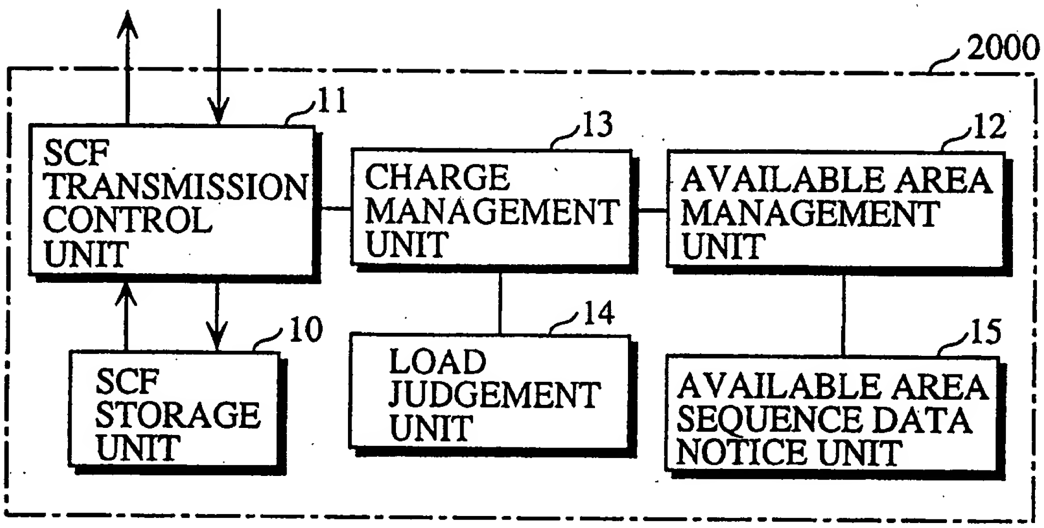

2000
11
SCF TRANSMISSION CONTROL UNIT
13
CHARGE MANAGEMENT UNIT
12
AVAILABLE AREA MANAGEMENT UNIT
10
SCF STORAGE UNIT
14
LOAD JUDGEMENT UNIT
15
AVAILABLE AREA SEQUENCE DATA NOTICE UNIT

FIG. 61

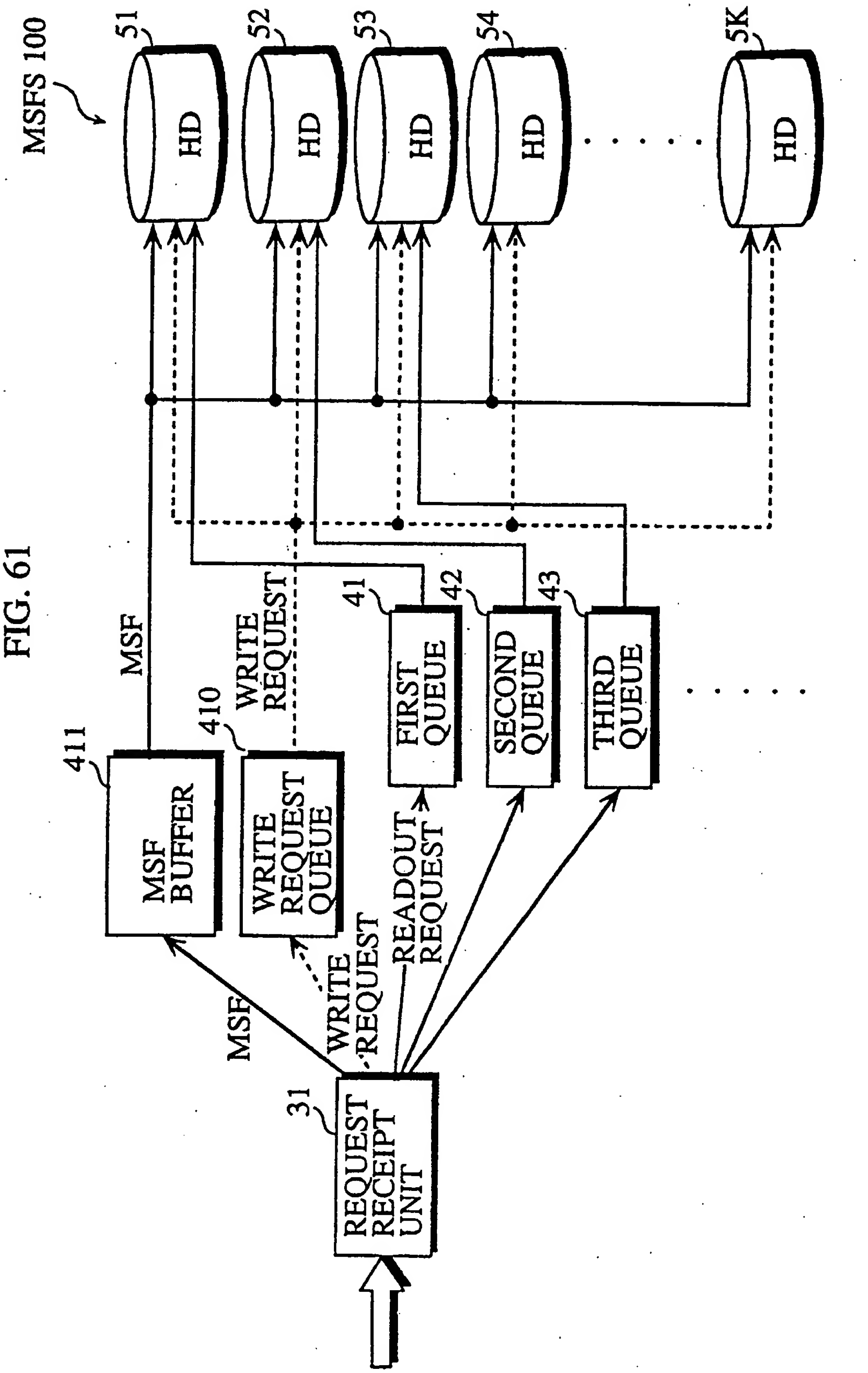
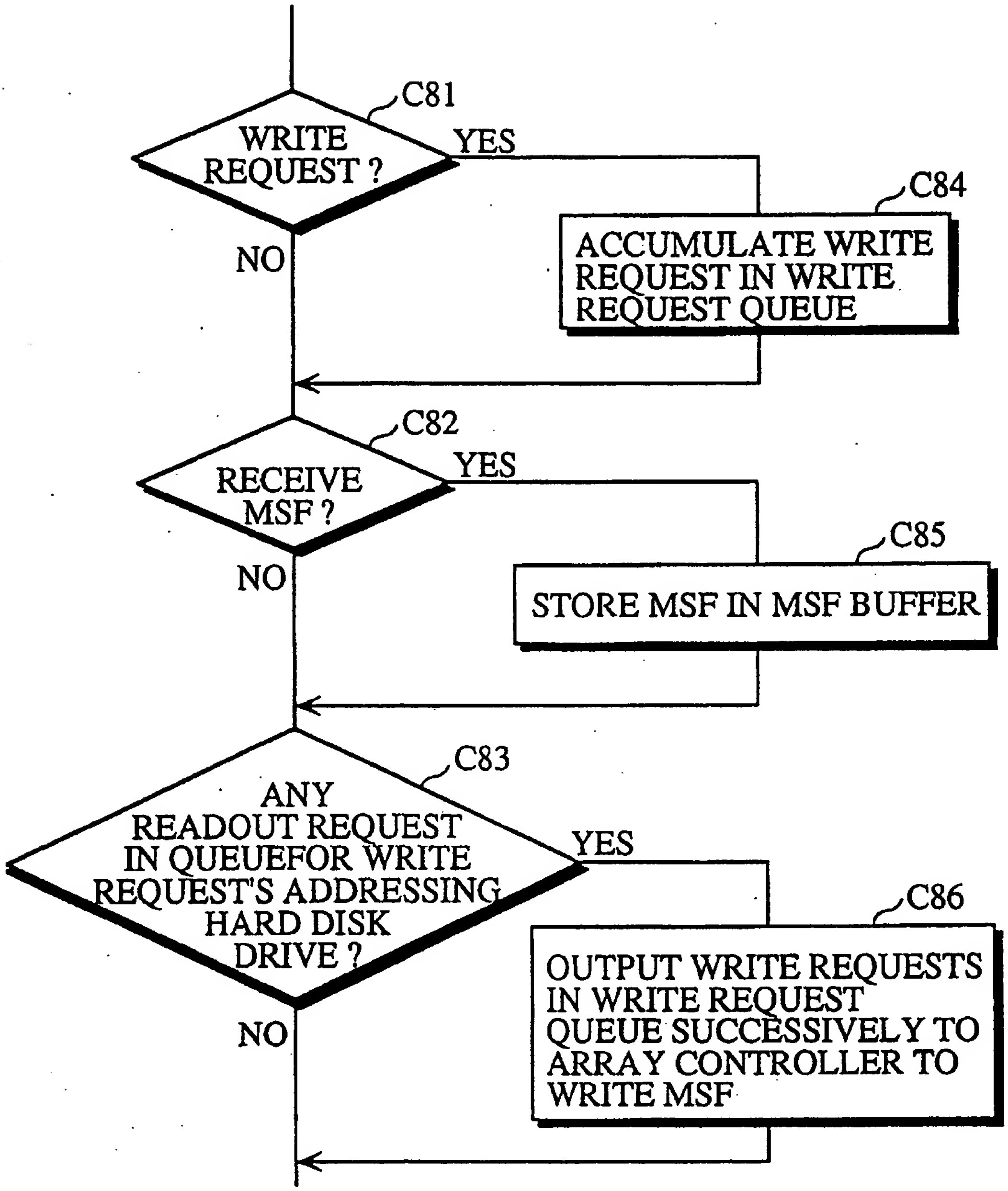

MSFS 100
51
52
53
54
5K
HD
HD
HD
HD
HD
MSF
WRITE REQUEST
41
42
43
FIRST QUEUE
SECOND QUEUE
THIRD QUEUE
411
410
MSF BUFFER
WRITE REQUEST QUEUE
READOUT REQUEST
MSF
WRITE REQUEST
31
REQUEST RECEIPT UNIT

FIG. 62


C81
WRITE REQUEST ?
YES
NO
C84
ACCUMULATE WRITE REQUEST IN WRITE REQUEST QUEUE
C82
RECEIVE MSF ?
YES
NO
C85
STORE MSF IN MSF BUFFER
C83
ANY READOUT REQUEST IN QUEUEFOR WRITE REQUEST'S ADDRESSING HARD DISK DRIVE ?
YES
NO
C86
OUTPUT WRITE REQUESTS IN WRITE REQUEST QUEUE SUCCESSIVELY TO ARRAY CONTROLLER TO WRITE MSF

VIDEO SERVER

BACKGROUND OF THE INVENTION

(1) Field of the Invention

The present invention relates to a video server which can transmit a video as per request among a plurality of videos stored therein.

(2) Description of the Related Art

There has been active research for an interactive television system in the field of CATV (Cable Television) system, and the core of the system is a video server.

In the interactive television system, each subscriber requests a video (program) he would like to watch to the CATV station, and the station transmits the videos as per requests to individual subscribers. Thus, the interactive television system enables the subscribers to enjoy the videos at any convenient time once it is put into practical use.

Among various applications of the interactive television system, the on-demand television system has been already made available to the public. The on-demand television system comprises a video tape library, a plurality of video tape players for playing the video tapes, a plurality of TV (television) cables for transmitting a plurality of videos being played to terminals equipped at the subscribers' end, and a switch for switching the TV cables.

The entire system is controlled manually by a plurality of operators at the station. To be more specific, upon receipt of the requests from the subscribers, the operators connect the TV cables to the their terminals by means of the switch, and play the video as per their requests by means of the video tape players. Accordingly, each video being played is transmitted to their respective subscribers via the connected TV cables.

However, such a manual control limits the service of the on-demand television system to a small number of subscribers. For example, it is well assumed to receive 100 requests at a time if there are 1000 subscribers. However, it is almost impossible to manage all the requests simultaneously under the manual control; there is a considerable lag time between the time the requests are received and the transmission of the requested videos.

Given these circumstances, the pure-on-demand television system was proposed in "Nikkei Communication" No. 144, pp. 38–55, Feb. 15, 1993, and "Nikkei Electronics", No. 584, pp. 58 as an ideal interactive television system, and it has been attracting public interests.

The pure-on-demand television system comprises a storage unit for storing digital data of the videos, a plurality of cables for transmitting the digital video data to individual subscribers, a plurality of decoders for generating visible images by decoding the transmitted digital video data, and an ATM (Asynchrnous Transfer Mode) switch for switching the cables.

Since the videos are transmitted in the form of digital data, they are processed quickly, and the subscribers can not only play the videos in real time whenever they want, but also play the videos quickly in both directions (fast-forward and fast-rewind) in real time as if they were manipulating the video tape player.

However, even with this ideal system the problem of the time lag is not solved. This is because a myriad of requests are sent to one storage unit at a time, and it takes time to read out the requested video data from the storage unit. In addition, it takes time to transmit the readout data to the subscribers by the means of the ATM switch when there is considerable traffic therein. Thus, the time lags caused in both reading out and transmitting the video data make the real time transmission impossible.

SUMMARY OF THE INVENTION

Accordingly, the present invention has a first object to provide a video server that can send video data in real time when a plurality of requests are received at a time.

The present invention has a second object to provide a video server that can rewrite the video data while transmitting the same.

The present invention has a third object to provide a video server that can construct a large scale interactive television system.

The first object can be fulfilled by a video server which transmits digital video data stored therein to subscriber terminals as per video requests comprising: a plurality of frame block servers, each including an image memory and a readout control unit for the image memory, each image memory storing a plurality of frame blocks, each frame block being one of sections forming a piece of digital video data, the readout control unit receiving readout requests and in response reading out requested frame blocks from the image memory; a management unit for storing management data specifying which frame block server stores which frame block in the image memory; a plurality of subscriber interfaces for receiving the video requests from the subscriber terminals, and in response sending readout requests to the frame block servers to readout the frame blocks forming requested digital image data in a predetermined sequence while referring to the management data, and for transmitting the frame blocks transmitted from the frame block servers to the subscriber terminals at such timing that ensures a continuous play; and an exchange unit for interconnecting each block server and each subscriber interface to transfer the frame blocks read out from the frame block servers as per the readout requests to the request-sender subscriber interfaces.

The management data may comprise a plurality of block pointers, each identifying a location of each frame block respectively, and including an address of each frame block server that stores each frame block respectively, and each subscriber interface may include: a management data obtainment unit for receiving the video request from the subscriber terminal, and in response retrieving block pointers for the requested piece of digital video data from the management unit; a readout request generation unit for generating a readout request for each retrieved block pointer addressing to the frame block server specified by the address included therein; a readout request transmission unit for transmitting the readout requests to the specified frame block servers, one readout request being transmitted at a time; and a frame block output unit for receiving the frame blocks read out as per the readout requests, and in response outputting the frame blocks to the request-sender subscriber terminal at predetermined timing.

The frame block output unit may include: a frame block receipt unit for receiving the frame blocks addressed to the self's subscriber interface; a block buffer for accumulating a certain number of frame blocks received by the frame block receipt unit; an accumulated amount judgment unit for judging whether the block buffer stores more than a predetermined number of frame blocks; and an output unit for outputting the certain number of the frame blocks accumulated in the block buffer when the accumulated amount judgment unit judges that the block buffer stores more than the predetermined number of frame blocks, one frame block being outputted at a time to the request-sender subscriber terminal.

Each subscriber interface may be connected to a plurality of subscriber terminals, each subscriber terminal outputting a video request including a terminal identifier, and the management data obtainment unit may further include an identifier detection unit for detecting the terminal identifiers contained in the video requests sent from the subscriber terminals upon receipt thereof, and the readout request transmission unit may further include an identifier attachment unit for attaching the terminal identifiers detected by the identifier detection unit to reach readout request generated by the readout request generation unit, and the readout control unit in each frame block server may include: a readout request receipt unit for detecting the terminal identifiers when receiving the readout requests from the readout request transmission unit; and a frame block transmission unit for attaching the terminal identifiers detected by the readout request receipt unit to each request frame block read out as per the readout requests before the transmission thereof to the request-sender subscriber interface, and the frame block output unit may further include a distribution output control unit for receiving the terminal-identifier-attached frame blocks and in response outputting the same to the request-sender subscriber terminal identified by the terminal identifier.

The exchange unit may be an ATM cell switch for exchanging cells, and each image memory may be a disk array comprising K disk drives for storing the frame blocks, and each block pointer may include an address of each frame block server storing each frame block, and an address of the frame block in the disk array, and the readout request may be of a cell structure, and the readout request transmission unit writes the address of the frame block server in a header area of the cell structure while writing the address of the frame block in the disk array in a data area of the cell structure to generate a readout request for each block pointer, and the readout control unit in the frame block server may detect the address of the frame block in each readout request and read out the requested frame block by accessing to the address of the disk array.

The readout control unit in each frame block server may include: K queues for holding the readout requests to read out the requested frame blocks from corresponding disk drives in an order of receipt, one queue being furnished for one disk drive; a readout request receipt unit for receiving the readout requests addressed to the self's frame block server; an address analysis unit for detecting the address of the requested frame block contained in each readout request received by the readout request receipt unit and in response specifying the disk drives to which each readout request is addressed using the detected address, and for having the queue furnished for the specified disk drive store the readout request; a disk access unit for retrieving one readout request from the K queues, and in response accessing to a memory area in the specified disk drive at the address contained in the readout request to have the disk drive read out the requested frame block; a transmission stand-by buffer for holding the frame blocks read out from the K disk drives; and a frame block transmission unit for retrieving the frame blocks from the transmission stand-by buffer to transmit to the request-sender subscriber interface.

The frame block transmission unit may include: a readout request storage unit for storing a readout request for which a requested frame block has been read out and stored in the transmission stand-by buffer together with a correlation with the frame block; a frame block retrieval unit for retrieving the frame blocks from the transmission stand-by buffer; a request-sender detection unit for detecting a request-sender subscriber interface of the readout request for the frame block retrieved from the transmission stand-by buffer; a frame block division unit for dividing the retrieved frame block from the transmission stand-by buffer into a set of sub-blocks of an equal size; a writing unit for writing each sub-block into the data area of the cell structure, and writing the request-sender detected by the request-sender detection unit into the header area of the cell structure; and a cell transmission unit for transmitting the cells written with the sub-block and the request-sender subscriber interface to the request-sender subscriber interface.

According to the above construction, upon receipt of a video request, the data of the requested video are readout per frame block from a plurality of frame block servers in a predetermined sequence and transmitted to the request-sender terminal, and thus enabling real time video transmission.

When there are a plurality of requests to one video, each frame block server reads out the frame blocks independently and sends the same to each terminal simultaneously. Thus, a plurality of subscribers can access to one video at one same time.

Further, since the ATM switch operates asynchronously which each image memory and readout out unit, the number of the subscribers and the kinds of videos can be changed relatively easy in the interactive system.

The second object can be fulfilled by a video server which transmits digital video data stored therein to subscriber terminals as per video request and which can rewrite the digital video data comprising: a plurality of frame block servers, each including an image memory, a readout control unit for the image memory, and a writing control unit for the image memory, each image memory storing a plurality of frame blocks, each frame block being one of sections forming a piece of digital video data, the read control unit receiving readout requests and in response reading out requested frame blocks from the adequate image memory, the write control unit receiving a write request and in response writing the frame blocks into the image memory; a management unit for storing management data specifying which frame block server stores which frame block in the image memory and which frame block server has a writable area in the image memory, and for updating the management data each time a frame block is written in the image memory; a plurality of subscriber interfaces for receiving the video requests from the subscriber terminals, and in response sending readout requests to frame block servers to readout frame blocks forming requested digital image data in a predetermined sequence while referring to the management data, and for transmitting the frame blocks transmitted from the frame block servers to the subscriber terminals at such timing that ensures continuous video-play; a write interface for obtaining a digital video to divide the digital video into a set of sections, and for transmitting the divided sections to the frame block servers having the writable areas together with the write request, each section being of a same size as the frame block; and an exchange unit for interconnecting each block server, each subscriber interface, and each write interface, and for transferring the frame blocks read out from the frame block servers and transmitted from the write interface to the request-sender subscriber interfaces and the frame block servers having the writable areas respectively.

The management data may comprise a plurality of block pointers, each identifying a location of each frame block respectively, and including an address of each frame block server that stores each frame block respectively, and each subscriber interface may include: a management data obtainment unit for receiving the video request from the subscriber terminal, and in response retrieving block pointers for the requested piece of digital video data from the management unit; a readout request generation unit for generating a readout request for each retrieved block pointer addressing to the frame block server specified by the address included therein; a readout request transmission unit for transmitting the readout requests to the specified frame block servers, one readout request being transmitted at a time; and a frame block output unit for receiving the frame blocks read out as per the readout requests, and in response outputting the frame blocks to the request-sender subscriber terminal at predetermined timing.

The image memory in each frame block server may have a memory area which is divided in a set of areas, each area being sufficiently large to record one frame block, and the management unit may include: a write pointer storage unit for storing write pointers, each write pointer being data showing a correspondence between the writable area in the image memory and its location; a write control data generation unit for retrieving the write pointers for each frame block server from the write pointer storage unit when the write interface receives the write request, and for aligning the retrieved write pointers in sequence to generate write control data for a piece of digital video data to be recorded; a management data conversion unit for converting the write control data generated by the write control data generation unit into the management data, and the write interface may include: a management data obtainment unit for receiving the write request, and in response retrieving the write pointers for the piece of digital video data to be recorded from the management unit; and a write request generation unit for generating a write request for each retrieved write pointer addressing to the frame block server specified by the write pointer; a division unit for generating a plurality of frame blocks by dividing the digital video data; a write request transmission unit for transmitting the write requests first and then the requested frame blocks to the specified frame block servers, one of one write request and requested frame block being transmitted at a time, and wherein each specified frame block server writes the frame block on the writable area in the image memory specified by the write request when the write request and the frame block are received.

The exchange unit may be an ATM cell switch for exchanging cells, and each image memory may be a disk array comprising K disk drives for storing the frame blocks, and each block pointer may include an address of each frame block server storing each frame block, and an address of the frame block in the disk array, and each write pointer may include an address of a frame block server storing the corresponding frame block, and an address of the writable are in the disk array; the readout request may be of a cell structure, and the readout request transmission unit writes the address of the frame block server in a header area of the cell structure while writing the address of the frame block in the disk array in a data area of the cell structure to generate a readout request for each block pointer, and the write request transmission unit may write the address of the frame block server in the header area while writing the address of the writable area in the data area, and the readout control unit in the frame block server may detect the address of the frame block in each readout request and reads out the requested frame block by accessing to the address of the disk array, and the write control unit in the frame block server may detect the address of the frame block in each write request and writes the frame block in the writable area.

According to the above construction, the video data can be rewritten while being transmitted to their respective destination terminals, which makes a variety of videos available to the subscribers.

The third object can be fulfilled by a video server which transmits digital video data stored therein to subscriber terminals as per video requests comprising: a plurality of frame block servers, each including an image memory and a readout control unit for the image memory, each image memory storing a plurality of frame blocks, each frame block being one of sections forming a piece of digital video data, the readout control unit receiving readout requests and in response reading out requested frame blocks from the image memory; a management unit for storing management data specifying which frame block server stores which frame block in the image memory; a plurality of subscriber interfaces for receiving the video requests from the subscriber terminals, and in response sending readout requests to the frame block servers to readout the frame blocks forming requested digital image data in a predetermined sequence while referring to the management data, and for transmitting the frame blocks transmitted from the frame block servers to the subscriber terminals at such timing that ensures a continuous play; and an exchange network including a plurality of exchange units interconnected each other, each being selectively connected to a plurality of frame block servers and a plurality of subscriber interfaces for transferring the frame blocks addressed to the self's frame block server to the request-sender subscriber interfaces respectively.

The management data may comprise a plurality of block pointers, each identifying a location of each frame block respectively, and including an address of each frame block server that stores each frame block respectively, and each subscriber interface may include: a management data obtainment unit for receiving the video request from the subscriber terminal, and in response retrieving block pointers for the requested piece of digital video data from the management unit; a readout request generation unit for generating a readout request for each retrieved block pointer addressing to the frame block server specified by the address included therein; a readout request transmission unit for transmitting the readout requests to the specified frame block servers, one readout request being transmitted at a time; and a frame block output unit for receiving the frame blocks read out as per the readout requests, and in response outputting the frame blocks to the request-sender subscriber terminal at predetermined timing.

The exchange network may be an ATM cell switch for transferring the cells, and each image memory may be a disk array comprising K disk drives for storing the frame blocks, and each block pointer may include an address of each frame block server storing each frame block, and an address of the frame block in the disk array, and the readout request may be of a cell structure, and the readout request transmission unit may write the address of the frame block server in a header area of the cell structure while wiring the address of the frame block in the disk array in a data area of the cell structure to generate a readout request for each block pointer, and the readout control unit in the frame block server may detect the address of the frame block in each readout request and may read out the requested frame block by accessing to the address of the disk array.

The disk array may comprise K disk drives interconnected by a SCSI, and the address of the frame block may be formatted for a readout command in a SCSI system.

According to the above construction, the frame blocks can be transferred between a plurality of the ATM switches, and thus the scale of the video server can be extended.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other objects, advantages and features of the invention will become apparent from the following description thereof taken in conjunction with the accompanying drawings which illustrate specific embodiments of the invention. In the drawings:

FIG. 1 is a logical format of video data supplied by a video server of the present invention;

FIG. 2 is a view depicting the structure of a video server in accordance with a first embodiment of the present invention;

FIG. 3 is a view explaining how each MSFS (Media Segment File Server) stores MSFs (Media Segment Files);

FIG. 4 is a view showing a logical format of an SCF (Sequence Control File) and MSFPs (Media Segment File Pointers);

FIG. 5 is a view depicting the structured of an SM (System Manager) shown in FIG. 2;

FIG. 6 is the control sequence of the video server in transmitting the SCFs and MSFPs;

FIG. 7 is a flowchart detailing the operation of an SCF transmission control unit;

FIG. 8 is a view depicting the structure of an SCB (Sequence Control Broker) shown in FIG. 2;

FIG. 9 is a flowchart detailing the operation of an MSFP transmission control unit;

FIG. 10 is a view depicting the structure of the MSFS shown in FIG. 2;

FIGS. 11A and 11B are the flowcharts detailing the operation of an array controller shown in FIG. 10;

FIG. 12 is a view explaining how the data per sector are converted into cells;

FIG. 13 is a flowchart detailing the operation of a communication control unit;

FIG. 14 is a view explaining how a transmission unit shown in FIG. 10 transmits the MSFs;

FIG. 15 is a view depicting the structure of a video server installed in a CATV station;

FIG. 16 is the control sequence of the video server when recording the MSFs;

FIG. 17 is a view depicting the structure of an SCB in accordance with a second embodiment of the present invention;

FIG. 18 is a view explaining how a delay management unit shown in FIG. 17 manages the delay times;

FIG. 19 is the control sequence of a video server in accordance with the second embodiment;

FIG. 20 is a view depicting the structure of an MSFS in accordance wit a third embodiment of the present invention;

FIG. 21 is the control sequence of a video server in accordance with the third embodiment;

FIG. 22 is a view depicting the structure of an MSFS in accordance with a fourth embodiment of the present invention;

FIG. 23 is a flowchart detailing the operation of a communication control unit in accordance with the fourth embodiment;

FIG. 24 is a flowchart detailing the operation of a communication control unit in accordance with a fifth embodiment of the present invention;

FIG. 25 is a view depicting the structure of an ATM switch in accordance with the fifth embodiment;

FIG. 26 is a view explaining how the cells are exchanged by the ATM switch in the fifth embodiment;

FIG. 27 is a view depicting the structure of a network in accordance with a sixth embodiment of the present invention;

FIG. 28 is a flowchart detailing the operation of a monitor control unit shown in FIG. 27;

FIG. 29 is a flowchart detailing the operation of a monitor control unit in accordance with a seventh embodiment of the present invention;

FIG. 30 is a view depicting the structure of an MSFS in accordance with an eighth embodiment of the present invention;

FIGS. 31A and 31B are the views explaining how authorization is granted;

FIG. 32 is a flowchart detailing the operation of a readout unit shown in FIG. 30;

FIG. 33 is a state diagram of a hard disk drive;

FIG. 34 is a flowchart detailing the operation of a queue length management unit shown in FIG. 30;

FIG. 35 is a flowchart detailing the operation of a selection specification unit shown in FIG. 30;

FIG. 36 is a view showing a major part of an MSFS in accordance with a ninth embodiment of the present invention;

FIG. 37 is a flowchart detailing the operation of a readout unit in accordance with the ninth embodiment;

FIG. 38 is a flowchart detailing the operation of a queue length management unit in accordance with the ninth embodiment;

FIG. 39 is a flowchart detailing the operation of a selection specification unit in accordance with the ninth embodiment;

FIG. 40 is a data format of a second data request in accordance with a tenth embodiment of the present invention;

FIG. 41 is a view depicting the structure of an SCB in accordance with the tenth embodiment;

FIG. 42 is a view depicting the structure of an MSFS in accordance with the tenth embodiment;

FIG. 43 is a flowchart detailing the operation of a second-data-request receipt unit shown in FIG. 41;

FIG. 44 is the data format of a first data request;

FIGS. 45A through 45C are the views explaining how issuance is scheduled by an issuance time management unit shown in FIG. 41;

FIG. 46 is a flowchart detailing the operation of the issuance time management unit;

FIG. 47 is a flowchart detailing the operation of a first-data-request transmission judgment unit;

FIG. 48 is a flowchart detailing the operation of a first-data-request transmission unit;

FIGS. 49A and 49B are the timing charts of the issuance of the first and second data requests;

FIG. 50 is a flowchart detailing the operation of an MSF distribution unit;

FIG. 51 is a flowchart detailing the operation of a first-data-request receipt unit;

FIG. 52 is a flowchart detailing the operation of a data readout transmission control unit;

FIG. 53 is a flowchart detailing the operation of a data transmission unit;

FIG. 54 is a view depicting the structure of a copy unit in accordance with an eleventh embodiment of the present invention;

FIG. 55 is a flowchart detailing the operation of an array controller in accordance with the eleventh embodiment;

FIG. 56 is a view showing an example of an MSF transmission management table in accordance with a twelfth embodiment of the present invention;

FIG. 57 is a flowchart detailing the process upon receipt of a readout request in the twelfth embodiment;

FIG. 58 is a flowchart detailing the MSF transmission process in the twelfth embodiment;

FIG. 59 is a flowchart detailing the operation of an SCF obtainment control unit in accordance with a thirteenth embodiment of the present invention;

FIG. 60 is a view depicting the structure of an SM in accordance with a fourteenth embodiment of the present invention;

FIG. 61 is a view depicting the structure of an MSFS in accordance with the fourteenth embodiment; and

FIG. 62 is a flowchart detailing the operation of a communication control unit in accordance with the fourteenth embodiment.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

First Embodiment

The format of the digital video data supplied by a video server **100** in accordance with the first embodiment of the present invention is shown in FIG. **1**. The digital video data are compressed by, for example, the MPEG (Motion Pictures Expert Group) 2 method, and divided into a set of 64 Kbyte files; hereinafter the resulting files are referred to as MSFs (Media Segment Files) which are numbered with their respective sequence numbers in one program as shown in FIG. **1**: (MSF)(1), MSF(2), MSF(3), MSF(4), ... For example, a 10-minute long MPEG 2 video with a transmission rate of 6.4 Mbps (bit per second) is divided into 7500 MSFs.

FIG. **2** is a block diagram showing the structure of the video server **100**. The video server **100** comprises a plurality of MSFSs (Media Segment File Servers) **1000**, **1001**, **1002**, **1003** . . . , an SM (System Manager) **2000**, a plurality of SCBs (Sequence Control Brokers) **3000**, **3001**, **3002**, **3003**, . . . , an ATM switch **4000**, and an FD (File Distributor) **5000**.

Each MSFS includes a SCSI (Small Computer System Interface) disk array for storing a plurality of MSFs and transmits the same. How each MSFS stores the MSFs will be explained while referring to FIG. **3**.

In the drawing, each rectangle represents one MSFS while squares within each rectangle representing the MSFs stored therein, and the MSFs forming one program are stored separately in the MSFSs. Assume that there is 1000 MSFSs, PROGRAM **1** consists of 2000 MSFs and each of PROGRAMS **2** and **3** consists of 1000 MSFs, then the MSF(1) of PROGRAM **1** is stored in the MSFS **1000**, (MSF(2) in the MSFS **1001**, MSF(3) in the MSFS **1002**, . . . , MSF(1000) in the MSFS **1999**, MSF(1001) in the MSFS **1000**, MSF(1002) in the MSFS **1001**, MSF(1003) in the MSFS **1002**, . . . , and MSF(2000) in the MSFS **1999**. Similarly, the MSF(1) of PROGRAM **2** is stored in the MSFS **1000**, MSF(2) in the MSFS **1001**, . . . , and MSF(1000) in the MSFS **1999**; the MSF(1) of PROGRAM **3** is stored in the MSFS **1000**, MSF(2) in the MSFS **1001**, . . . , and MSF(1000) in the MSFS **1999**.

If a 10-minute long MPEG2 video consisting of 7500 MSFs are stored in 100 MSFSs, 75 MSFs are stored in each MSFS.

Each MSFS transmits the MSFs thus stored to the ATM switch **4000** as per readout requests send from the SCBs **3000**, **3001**, **3002**, **3003** . . . by means of the ATM switch **4000**.

The SM **2000** stores SCFs (Sequential Control Files) for each program and transmits the same: when the SM **2000** receives an SCF obtainment request from the SCBs **3000**, **3001**, **3002**, . . . , it transmits the requested SCF to the request-sender SCB by means of the ATM switch **4000**. The SCF is the data used to convert the MSFs stored separately in the MSFSs into the video data of one program, and consists of MSFPs (Media Segment File Pointers) that indicate which MSF is stored in which MSFS. Examples of the SCF and MSFPs are shown in FIG. **4**. The MSFPs are aligned according to the sequence of the corresponding MSFs, and each MSFP consists of data related to the MSFS storing the MSF, a sequence number at which the MSF is read out or written in, and a command assigned to the MSFP. The MSFS data consist of an MSFS's address (the one managed by the ATM switch **4000**), a number specifying an SCSI of a disk storing the MSF (4 bits), a number specifying the disk (4 bits), and a number specifying a logical block indicating the MSF's storage location (20 bits). The command specifies which disk control command is assigned to the MSFP, and a "read" command is assigned in general. Thus, since each MSFP includes parameters of the read command for the disk array, it also serves as a disk control command to read out the data by accessing to the disk array.

The SCBs **3000**, **3001**, **3002**, **3003**, . . . are equipped on subscriber lines connecting the ATM switch **4000** and terminals installed at each subscriber's end, and responsible for the program request transmission, MSFP transmission, and MSF reception defined as follows.

The program request transmission by the SCBs means to have the SM **2000** transmit the SCF including the MSFPs for a selection request sent from the terminal by retrieving the data related to the program from the selection request.

The MSFP transmission by the SCBs means to have the MSFSs **1000**, **1001**, **1002**, . . . transmit the MSFs specified by the MSFPs in the SCF transmitted from the SM **2000** by generating readout requests using the MSFPs and transmitting the same by means of the ATM switch **4000**.

The MSF reception by the SCBs means to receive the MSFs successively transmitted from the MSFSs **1000**, **1001**, **1002**, . . . by means of the ATM switch **4000** and align the same sequentially to output the same to the terminal as the original digital video data.

The ATM switch **4000** is an ATM switch that exchanges cells asynchronously, and all the readout request, SCF obtainment requests, SCFs and MSFs are converted into the cells to be transmitted by the ATM switch **4000**. The cells referred herein are the data consisting of a 5-byte header area and 48-byte data area. The header area includes a destination address and an area used to check the validity of the destination address. The ATM switch is explained in "Information Processing", Vol. 33, No. 2, February 1992, and further explanation is omitted herein. The destination addresses referred herein are the addresses of the SCBs **3000**, **3001**, **3002**, **3003**, . . . , MSFSs **1000**, **1001**, **1002**, **1003**, **1004**, . . . , and SM **2000**, and each cell travels within the video server **100** using these addresses.

The FD **5000** receives a digital-video signal in the form of the digital codes, and divides the same into a set of MSFs to write into the MSFS **1000**, **1001**, **1002**, . . . separately.

The terminal, to which the video sis supplied, comprises a display for showing a video transmitted from the video server **100**, a video selection panel enabling the subscriber to select a video, a playback mode selection panel enabling the subscriber to select a playback mode, and an output unit outputting a selection signal containing data related to the selected video and playback mode.

The structure of the SM **2000** is depicted in FIG. **5**. The SM **2000** comprises an SCF storage unit **10**, an SCF transmission control unit **11**, a charge management unit **13**, and a load judgment unit **14**.

More precisely, the SCF storage unit **10** stores the SCFs for each program in relation with their respective transmission rates. The transmission rate is directly proportional to the quality of the programs transmitted by the video server **100**. For example, the transmission rate is set at 6.0 Mbps for a high quality program, and 1.5 Mbps for a relatively low quality program.

THE SCF transmission control unit **11** controls the transmission of the SCFs, which will be explained while referred to FIGS. **6** and **7**. FIG. **6** is the sequence showing the video data readout operation within the video server **100**, and FIG. **7** is a flowchart detailing the operation of the SCF transmission control unit **11**. Assume that a subscriber selects a soccer news by means of his terminal, then a selection signal (Start_ Video) is inputted into one of the SCBs (herein **3000**) from the terminal. Accordingly, the SCB **3000** sends an SCF obtainment request (SCF_Get_Req) to the SCF transmission control unit **11** by means of the ATM switch **4000**. Upon receipt of the SCF obtainment request (SCF_ Get_Req) (S101), the SCF transmission control unit **11** retrieves the SCF corresponding to the soccer news from the SCF storage unit **10** (S102) and transmits the same (SCF_ Get_Rsp) to the request-sender SCB **3000** (S103).

The charge management unit **13** retrieves the SCF specified by the SCF obtainment request from the SCF storage unit **10** to detect the size thereof when the SCF transmission control unit **11** receives the SCF obtainment request, and sets the charges based on the detected size. By setting the charges depending on the SCF sizes, the charges become directly proportional to the video length.

The load judgment unit **14** determines whether the SCF obtainment request received by the SCF transmission control unit **11** should be accepted or rejected. Such judgment is made based on each program's transmission rate stored in the SCF storage unit **10** and the traffic within the ATM switch **4000**. In case of rejection, the load judgment unit **14** transmits a notice of rejection to the SCF transmission control unit **11**, which in return transmits the notice of rejection to the SCF-obtainment request-sender terminal via the SCB **3000** instead of the response (SCF_Get_Rsp).

The SCBs **3000**, **3001**, **3002**, . . . are of the same structure, and the SCB **3000** will be explained as an example while referring to FIG. **8** depicting the structure thereof.

The SCB **3000** comprises a selection signal separation unit **20**, a buffer memory **21**, a buffer memory monitor unit **22**, and an MSFS transmission control unit **23**.

More precisely, the selection signal separation unit **20** separates the selection signal sent from the terminal via a subscriber line **1** (SL1): upon receipt of the selection signal, it separates the same into a program request and a playback mode request; the former is transmitted to the SM **2000** by means of the ATM switch **4000** via a subscriber line **2** (SL2), and the latter to the MSFP transmission control unit **23** via a subscriber line **4** (SL4). The playback mode referred herein includes normal, fast, reverse, frame-by-frame, skip, still, and location-specifying modes.

The buffer memory **21** is a memory temporarily holding a predetermined length of MSFs successively transmitted from the MSFSs **1000**, **1001**, **1002**, . . . via a data line **2** (DL2) by means of the ATM switch **4000**. The buffer memory **21** outputs the MSFs to the terminal synchronously with a predetermined block signal via a data line **3** (DL3). The cycle of the clock signal is determined depending on the video length for one MSF. Assume that 1-second long video consists of 30 frames and one MSF corresponds to 10 frames, then the buffer memory **21** transmits one MSF every ⅓ second to the terminal.

The buffer memory monitor **22** monitors an available capacity of the buffer memory **21**.

The MSFP transmission control unit **23** includes an SCF buffer (not shown) withholding the SCFs transmitted from the SM **2000**, and controls the above-defined MSFP transmission. The operation of the MSFP transmission control unit **23** will be explained while referring to FIG. **6** and the flowchart in FIG. **9**.

The MSFP transmission control unit **23** receives the playback mode request from the selection signal separation unit **20** and the SCF from the SM **2000** by means of the ATM switch **4000**, and stores the SCF into the SCF buffer (S201). Subsequently, the MSFP transmission control unit **23** outputs a ready signal to the terminal and judges the selected playback mode (S202). Assuming that the normal mode has been selected, then the MSFP transmission control unit **23** determines to transmit the readout requests as per SCF (S203). Having determined the transmission sequence, the MSFP transmission control unit **23** outputs a start request (Tit_Start_Req) to the SM **2000**, and waits for a response (Tit_ Start_Rsp). Upon receipt of the response and SCF, the MSFP transmission control unit **23** generates readout requests for the requested video using the MSFPs in the SFC; the readout requests are in effect the cells storing the parameters of the MSFPs to convey the MSFPs to the MSFSs. In FIG. **6**, (MSF_Read_Req(1)) is the first readout request addressed to the MSFS **1000** (MSFS[1]), and MSF Read_Req(2)) and (MFS_Read_Req(3)) are the second and third readout requests addressed to the MSFS **1001** (MSFS[2]) and the MSFS **1002** (MSFS[3]) respectively.

Having generated the readout requests for the video, the MSFP transmission control unit **23** transmits the same to their respective MSFSs successively. For example, the MSFP transmission control unit **23** transmits the first readout request (MFS_Read_Req(1)) to the MSFS **1000** at a predetermined interval before the buffer memory **21** transmits the MSF[1] (S204, S205, S206), and transmits the following readout request (MSF_Read_Req(2)) and (MSF_Read_ Req(3)) at the predetermined interval before the buffer memory **21** transmits the MSF[2] and MSF[3] respectively S204, S205, S206). The predetermined interval referred herein is an estimated interval between the time when each readout request is transmitted and the receipt of the corresponding MSF, and it is calculated using the MSFS's MSF readout rate, ATM switch 4000's exchange ability, and the buffer memory 21's MSF transmission rate.

The MSFS 1000 reads out the MSF(1) as per the first readout request (MSF_Read_Req(1)) upon receipt thereof, and sends the same to the MSFP transmission control unit 23 as a response (MSF_Read_Rsp(1)). The MSF(1) thus readout is stored in the buffer memory 21 after some interval (Delay Time (1)) has passed.

Similarly, the responses (MSF_Read_Rsp(2)) and (MSF_Read_Rsp(3)) are successively transmitted to the MSFP transmission control unit 23 from the MSFS 1001 and MSFS 1002 after some intervals, (Delay Time (2)) and (Delay Time (3)) respectively, and the MSFP transmission control unit 23 stores the same into the buffer memory 21. The MSFs stored in the buffer memory 21 are successively transmitted to the terminal, which accordingly converts the MSFs into consecutive video data (Video_Data(1) and Video_Data (2)) first and then decodes the same while counting the number of the frames of the video data, playing the requested video.

While the memory buffer 21 stores the MSFs, the MSFP transmission control unit 23 periodically inquires the buffer memory monitor unit 22 whether there is an available capacity in the buffer memory 21. The MSFP transmission control unit 23 does so because the buffer memory 21 must have an available capacity to store the MSFs successively read out from the MSFSs as per readout requests: when the buffer memory 21 has an overflow or underflow within the predetermined interval, the MSFP transmission control unit 23 adjusts the timing of the readout request transmission.

When a pause request is inputted from the terminal, the pause request is transmitted to the MSFP transmission control unit 23 by means of the selection signal separation unit 20. The MSFP transmission control unit 23 accordingly has the buffer memory 21 suspend the MSF transmission to the terminal.

When resuming the video play, a resume request is transmitted to the MSFP transmission control unit 23 from the terminal with a number representing the frame from which the video-pay is resumed.

When the reverse mode is selected, the MSFP transmission control unit 23 arranges the sequence of the MSFPs in a manner reversed to the sequence in the SFC and determines the same as the readout request transmission sequence, for example, MSFP 1200–MSFP 1199–MSFP 1198–MSFP 1197.

When the skip mode is selected, the MSFP transmission control unit 23 arranges the sequence of the MSFPs by skipping a predetermined number of the MSFPs to determine the same as the readout request transmission sequence, for example, MSFP 1–MSFP 60–MSFP 120–MSFP 180.

When the location-specifying playback mode is selected, the MSFP transmission control unit 23 arranges the sequence of the MSFPs starting from an MSFP specified by the subscriber to determine the same as the readout request transmission sequence, for example, MSFP 301–MSFP 302–MSFP 303–MSFP 304.

While controlling the MSFP transmission, the MSFP transmission control unit 23 checks the last MSFP in the SCF by referring to the sequence number of the MSFSs in the readout requests, and once the MSFP transmission control unit 23 has transmitted the last readout request (S206), it waits for the following SFC (S201).

The MSFSs 1000, 1001, 1002, 1003, . . . are of the same structure, and the MSFS 1000 will be explained as an example while referring to FIG. 10 depicting the structure thereof. The MSFS 1000 comprises a request receipt unit 31, first through K'th queues 41 . . . 4K, a SCSI disk array 50 including first through K'th hard disk drives 51 . . . 5K, an array controller 60, a transmission stand-by buffer 62, a readout delay timer 64, a transmission unit 61, and a communication control unit 65.

The request receipt unit 31 receives the readout requests successively transmitted from the SCBs by means of the ATM switch 4000.

The queues 41 . . . 4K are furnished for the hard disk drives 51 . . . 5K respectively, and each accumulates the readout requests for the respective hard disk drives.

The disk array 50 includes the hard disk drives 51 . . . 5K which are interconnected each other by a SCSI and operate in parallel. Each hard disk drive comprises a disk whose memory is divided into a set of sectors each storing the 1024-byte data forming the MSF, a disk driving system, and a head for reading out the data in the sectors, and a seek system for seeking the head. Each hard disk drive reads out the data in the sectors by controlling the disk driving system and seek driving system. For this reason, not all the data are read out at the same readout rate: the readout rate is directly proportional to the distances between the head and the sectors. The disks in the hard disk drives 51 . . . 5K operate in parallel, and thus the hard disk drives 51 . . . 5K operate as if they were one unit by driving the disks alternately or sequentially. Note that one of the hard disk drives is exclusively used for code correction to ensure the reliability.

The array controller 60 controls the disk array 50 and MSF transmission. The operation of the array controller 60 will be explained while referring to the flowcharts in FIGS. 11A and 11B. In the drawing, Kdisk is a variable equal to 2 or more ($k \geqq 2$) that specifies the queues furnished for each hard disk drive and its disk in the disk array 50.

When the request receipt unit 31 receives the readout request (MSF_Read_Req) (S301), the array controller 60 analyses the same to specify the disk that contains the requested MSF. Assume that the requested MSF is stored in the k'th hard disk drive 5*k*, the array controller 60 stores the readout request into the corresponding k'th queue 4*k* (S302). When the k'th queue 4*k* receives the readout request (S303), the array controller 60 retrieves the readout request in the k'th queue (S304) to readout the MSF per sector (S305). When the readout operation completes (S306), the array controller 60 increments the queue number by one (S307).

The transmission unit 61 converts the MSFs read out from the disk array 50 per sector into a set of cells and outputs the same to the ATM switch 4000, which will be explained more in detail while referring to FIG. 12.

The transmission unit 61 attaches 24-byte ID data and 8-byte trailer to 1024-byte data of one sector, making 1056-byte data, divides the resulting 1056-byte data into a set of 48-byte data areas, and attaches a 5-byte header area to each generating 22 cells as a result. Having generated the cells, the transmission data 61 detects the SCB that has sent the readout request and stores the address thereof into the header area.

Because one MSF has a file size of 64 Kbytes, 64×22 (1048) cells are generated from one MSF, which are separately transmitted to the SCBs 3000, 3001, ... Since the transmission unit 61 carries out the above MSF-to-Cell conversion process 64×22 (1408) times to transmit one MSF, the MSFs read out from the disk array 50 are not transmitted instantaneously.

Also, the transmission unit 61 inquires whether the ATM switch 4000 has an overflow, and in case of overflow, to suspend the cell transmission until the overflow is eliminated.

The transmission stand-by buffer **62** is a FIFO (first-in-first-out) memory to withhold the MSFs read out from the disk array **50** to deliver the same to the transmission unit **61** in the readout sequence; for the readout MSFs are not transmitted instantaneously.

The readout delay timer **64** includes a plurality of counters that operate in parallel, and sets a timing to deliver the MSFs in the transmission stand-by buffer **62** to the transmission unit **61**.

The communication control unit **65** controls the MSF transmission by the MSFS **1000**, which will be explained while referring to the flowchart in FIG. **13**.

The communication control unit **65** monitors the receipt of a readout request by the request receipt unit **31**, and the completion of the MSF transmission by the transmission unit **61** (C**10**, C**11**). Upon detection of the readout request receipt in C**10**, the communication control unit **65** activates the readout delay timer **64** to count the time for the readout request (C**12**), and has the array controller **60** accumulate the readout request in the corresponding queue (C**13**). When the transmission unit **61** completes the transmission of one MSF in C**11**, the communication control unit **65** checks whether there is any MSF in the transmission stand-by buffer **62** (C**14**) to further check whether the time-out has come for the first-in MSF therein. (C**15**). When the time-out has come, the communication control unit **65** has the transmission stand-by buffer **62** deliver the first-in MSF to the transmission unit **61** (C**16**), which accordingly transmits the same to the ATM switch **4000**.

FIG. **14** details the timing control by the readout delay timer **64** described using the flowchart in FIG. **13**. When the request receipt unit **31** receives a readout request 3*a* at the timing of 3*a*1 (C**10**), the readout delay timer **64** start to count the time for the readout request 3*a*. Accordingly, the MSF3*a* is read out from the disk array **50** as per the readout request 3*a* and stored in the transmission stand-by buffer **62** at the timing of 3*a*2. Although it becomes possible for the transmission stand-by buffer **62** to transmit the MSF3*a* at the timing of 3*a*3 (C**11**), the MSF3*a* is not delivered to the transmission unit **61** until the readout delay timer **64** counts the time-out 3T. When the readout delay timer **64** counts 3T (3*a*4), the communication control unit **65** has the transmission stand-by buffer **62** deliver the MSF3*a* to the transmission unit **61** (C**16**).

Similarly, when the request receipt unit **31** receives readout request 3*b* and 3*c* at the timing of 3*b*1 and 3*c*1 respectively (C**10**), the readout delay timer **64** starts to count the time for each request. Then, the MSF3*b* is readout from the disk array **50** as per the readout request 3*b* and stored in the transmission stand-by buffer **62** at the timing of 3*b*2. Subsequently, the MSF3*c* is readout from the disk array **50** as per the read request 3*c* and stored in the transmission stand-by buffer **62** at the timing of 3*c*2. Note that the MSF3*a*, MSF3*b*, and MSF3*c* are readout at the different timing because the time required to read out the MSFs varies depending on where they are stored in the disks. Although it becomes possible for the transmission stand-by buffer **62** to deliver the MSF3*b* and MSF3*c* at the timing of 3*b*3 and 3*c*3 respectively (C**11**), neither the MSF3*b* nor MSF3*c* is delivered until the readout delay timer **64** counts 3T for each. When the readout delay timer **64** counts 3T for each (3*b*4 and 3*c*4), the communication control unit **65** has the transmission stand-by buffer **62** deliver the MSF3*b* and MSF3*c* to the transmission unit **61** (C**16**).

Due to the above timing control by the readout delay timer **64**, the MSFs are delivered to the transmission unit **61** at regular intervals from the receipt of their respective readout requests even when the MSFs are readout at different timing.

Following is the explanation of how the scale of an interactive system employing the above video server **100** will be determined.

First, the number of the subscribers (NSB) of the interactive system must satisfy Equation (1) as follows:

$$NSB<EX/(\rho\times rt) \tag{1}$$

where

EX is the ATM switch **4000**'s exchange ability;

rt is a transmission rate per video of the subscriber line connecting the SCBs and terminals;

ρ is the usage frequency per subscriber (times/second).

Now, let EX be 2.4 Gbps, rt be 1.5 Mbps, and ρ be 0.05, then we get NSB<32000.

Thus, the interactive television system employing the video server **100** can provide the service to approximately 32000 subscribers.

Then, the number of the MSFSs (NDB) is found by Equation (2) as follows:

$$NDB>EX/rr \tag{2}$$

where

rr is the MSFS's maximum retrieval rate.

Let rr be 12 Mbps, then we get NDB>200, which means the video server **100** must be furnished with 201 or more MSFSs.

Further, the number of subscribers (NACC) that can access to the video server **100** simultaneously is found by Equation (3) as follows:

$$NACC=NDB\times(rr/rt) \tag{3}$$

Thus, we get NACC=1600.

Also, the disk array **50** within each MSFS demands a capacity (DB×NB) calculated by Equation (4) as follows:

$$(DB\times NB)>Sm\times T\times rt/NDB \tag{4}$$

where

DB is the file size of one MSF;

NB is the maximum number of MSFs stored in one MSFS;

Sm is the number of the videos; and

T is the length of one video in time unit.

Let T be 3 minutes and Sm be 3000, then we get (DB×NB)=approximately 5 GB.

Further, a capacity (B) of the buffer memory **21** is found by Equation (5) as follows:

$$B>tr\ (rr-rt)=\{1-(rt/rr)\}\cdot DB \tag{5}$$

tr(=DB/rr) is the time required to transmit one MSF from the MSFS to the SCB; and

tt(=DB/rt) is the time required to transmit one MSF from the SCB to the terminal.

For the interactive system constructed as above, PC/AT compatible personal computers installing an ATM interface card for the cell transmission and an i486DX-2-66 CPU (Intel Corp.) can be used as the MSFS **1000**, **1001**, **1002**, . . . , SM **2000**, SCBs **3000**, **3001**, **3002**, ...

According to the first embodiment, when a video is requested from the subscriber, the MSFs forming the requested video are read out from a plurality of MSFSs in a predetermined sequence and successively transmitted to the request-sender subscriber via the subscriber line, making the read time access possible without having the subscriber kept waiting.

Also, by transmitting the MSFs consecutively at regular intervals even when the MSFs are read out at different timing, the video is transmitted continuously.

In this embodiment, the SCF stores the readout sequence of all the MSFs in one program; however, it may store only the MSFS's address of the first MSF of the program and its sequence number to have each hard disk drive store the addresses of the following MSFs (such as the address of the MSFS **1000**). In this case, when the first MSF is read out, a chain of the following MSFs is read out. That is to say, each time one MSF is read out from the corresponding hard disk drive, the MSFP transmission control unit **23** receives the address of the following MSF and sends the readout request to the corresponding hard disk drive.

Also, the MSFP transmission control unit **23** sends the readout requests for the second and onwards MSFs sequentially at the predetermined interval before the buffer memory **21** transmits the corresponding MSF in the first embodiment. However, the MSFP transmission control unit **23** may transmit the same each time an adequate capacity becomes available in the buffer memory **21** or when most of the MSFs in the buffer memory **21** have been transmitted using the buffer memory monitor unit **22**.

The MSFSs, SM and SCBs are not necessarily provided separately, the MSFS and SCB may be one unit.

The MSFs may be transmitted at irregular intervals to the terminals in the form of packets.

Second Embodiment

In the second embodiment, each SCB counts the delay time between the transmission of the readout request and the receipt of the requested MSF, and exploits the delay time for the following readout request transmission. Thus, each SCB in the second embodiment additionally includes a delay management unit **24** as shown in FIG. **17**.

The delay management unit **24** counts the time between the transmission of the readout request and the receipt of the requested MSF as a delay time, and manages the delay times in relation with the individual MSFSs as delay data. An example of the delay data is shown in FIG. **18**, and the delay management unit **24** manages the delay times for the readout request to MSFS **1000**, MSFS **1001**, and MSFS **1002** separately. Further, the delay management unit **24** directs the MSFP transmission control unit **23** to transmit the readout requests based on the delay data.

FIG. **19** shows an example of a control sequence of the MSFP transmission control unit **23** and MSFSs **1000**, **1001**, **1002**, ... In the drawing, (**1***a*, A101) is a readout request addressed to the MSFS **1000** to read out MSF(A101). Similarly, (**1***b*, A102) is a readout request addressed to the MSFS **1001** to read out the MSF(A102), and (**1***c*, A103) is a readout request addressed to the MSFS **1002** to readout the MSF(A103). The control sequence shows that the MSFP transmission control unit **23** transmits these readout requests to the corresponding MSFSs **1000**, **1001**, **1002** and the buffer memory **21** receives the requested MSFs (A101), (A102), and (A103) after the delay management unit **24** has counted the delay times Da, Db, and Dc, respectively. Accordingly, the delay management unit **24** subtracts the predetermined interval explained in the first embodiment from the delay times and notifies the balance to the MSFP transmission control unit **23**. By so doing, in case of FIG. **19**, the delay management unit **24** have the MSFP transmission control unit **23** transmit a readout request (**10***a*, A110) addressed to the MSFS **1009** (not shown) to readout the MSF(A110) at an interval corresponding to the balance before the predetermined interval. By managing the delay time for each MSFS and transmitting the readout requests by taking the delay time into account, the requested MSFs are received at regular intervals even when they are transmitted at different timing.

In the second embodiment, the delay times are managed in relation with the individual MSFSs; however, the delay time for the latest readout request to the same MSFS may be used instead. In this case, the latest delay time is compared with the delay time in the delay data, and when the two values do not coincide, the latter is updated by the former.

Third Embodiment

In the third embodiment, each MSFS estimates the delay time depending on the number of the accumulated readout requests, and notifies the estimated delay time to the SCB (herein **3000**) that has sent the readout request besides the effects realized by the second embodiment.

Thus, as shown in FIG. **20**, the MSFS **1000** in the third embodiment includes a delay data transmission unit **66** instead of the readout delay timer **64** to notify the estimated delay time value to the SCB **3000**.

The delay data transmission unit **66** estimates the time required to complete a readout request received by the request receipt unit **31** depending on the number of the readout requests accumulated in the corresponding queue. When the estimated time exceeds a predetermined value, the delay data transmission unit **66** converts the estimated value into the cells, and transmits the same to the delay management unit **24** in the SCB **3000** as a delay notice. Having received the delay notice, the delay management unit **24** manages the estimated time in the delay notice as the delay time for the MSFS **1000**.

The operation of the delay data transmission unit **66** will be explained while referring to FIG. **21** showing an example of a control sequence of the MSFP transmission control unit **23** and MSFSs **1000**, **1001**, **1002**, ... In the drawing, (**1***a*, A101) is a readout request addressed to the MSFS **1000** to readout MSF(A101). Similarly, (**1***b*, A102) is a readout request addressed to the MSFS **1001** to readout MSF(A102) and (**1***c*, A103) is a readout request addressed to the MSFS **1002** to readout MSF(A103).

Assume that the readout request (**1***c*, A103) received by MSFS **1002** is accumulated in the corresponding queue, then the delay data transmission unit **66** estimates the delay time for the readout request (**1***c*, A103) by taking into account the queue length (the number of the readout request accumulated in the queue), and returns the estimated delay time Dc' as the delay notice to the delay management unit **24** in the SCB **3000**. Then, the delay management unit **24** directs the MSFP transmission control unit **23** to transmit the following readout request by taking into account the delay time Dc'.

By managing the estimated delay time for each MSFS and sending the readout requests by taking the estimated delay time into account, the MSFs are received at regular intervals when the MSFs are transmitted at different timing.

Fourth Embodiment

In the fourth embodiment, each SCB counts the time between the transmission of the readout request and the receipt of the requested MSF, and when the counted time exceeds a predetermined time **Td1**, the SCB discards the received MSF.

To be more efficient, each MSFS in the fourth embodiment also discards the MSFs which are likely to be discarded by the SCBs before it transmits such MSFs to the ATM switch **4000**.

Thus, each MSFS in the fourth embodiment includes a transmission delay timer **81** instead of the readout delay timer **64** and a communication control unit **82** instead of the communication control unit **65** as shown in FIG. 22.

The transmission delay timer **81** is of the same structure as the readout delay timer **64**; however, it counts a waiting time for each MSF in the transmission stand-by buffer **62**, and the maximum waiting time is set as the time-out **Tm1** using Equation 6 as below.

$$Tm1=Td1-Ta1-Tb1 \qquad (6)$$

wherein

Ta1 is the minimum delay time between the transmission of the readout request from the SCB **3000** and the delivery of the requested MSF to the transmission unit **61**;

Tb1 is the minimum delay time between the transmission of the MSF from the transmission unit **61** and the receipt of the same at the SCB **3000**.

The communication control unit **82** controls the communication within the MSFS **1000**, and whose operation will be explained while referring to the flowchart in FIG. 23. Since the flowchart is partly identical with the flowchart in FIG. 13, only the different steps will be explained.

The communication control unit **82** monitors the receipt of a readout request at the request receipt unit **31** (C10), a new MSF in the transmission stand-by buffer **62** (C21), the completion of the MSF transmission by the transmission unit **61** (C11), and time-out MSFs (C23).

When the request receipt unit **31** has not received any readout request in C10, and a new MSF is stored in the transmission stand-by buffer **62** in C21, the communication control unit **82** activates the transmission delay timer **81** to start to count the waiting time for the new MSF (C24). When the transmission unit **61** has completed the transmission of one MSF (C22), the communication control unit **82** checks whether there is any MSF in the transmission stand-by buffer **62** (C14) to have the transmission stand-by buffer **62** deliver the first-in MSF therein to the transmission unit **61**, while having the transmission delay timer **81** reset the counting value for the delivered MSF (C27).

When the communication control unit **82** detects the time-out MSF in C23, it discards such an MSF (C28) and has the transmission delay timer **81** reset the counting value for the discarded MSF (C28).

By discarding the MSFs that have been withheld in the transmission stand-by buffer **62** for a long time in each MSFS, most of the MSFs that are likely to be discarded by the SCBs are discarded before they are transmitted to the ATM switch **4000**, and thus reducing the load to the ATM switch **4000**.

The time between the MSF delivery from the transmission stand-by buffer **62** and the MSF transmission by the transmission unit **61** is counted in this embodiment. However, the time between the receipt of the readout request and the transmission of the requested MSF at each MSFS may be counted instead.

Fifth Embodiment

In the fifth embodiment, priority is given to the cells converted from the MSFs that took a considerably long time to be read out.

Thus, the MSFS **1000** in the fifth embodiment is of the same structure as the MSFS **1000** in the first embodiment except that the communication control unit **65** has the transmission unit **61** set a delay level in each cells forming the MSFs.

The communication control unit **65** transmits the cells by the transmission unit **61** after the transmission unit **61** has set a low delay level to each when the corresponding MSF is read out before the time-out, and a high delay level when it is readout after the time-out.

The operation of the communication control unit **65** will be explained while referring to the flowchart in FIG. 24. The flowchart in FIG. 24 is partly identical with the flowcharts in FIGS. 13 and 23, and only the different steps will be explained.

The communication control unit **65** monitors the receipt of a readout request at the request receipt unit **31** (C10), a new MSF in the transmission stand-by buffer **62** (C21), the completion of the MSF transmission by the transmission unit **61** (C11), and time-out MSFs (C23).

When the request receipt unit **31** receives a readout request in C10, the communication control unit **65** activates the readout delay timer **64** to start to count the waiting time for the readout request (C12), and has the array controller **60** accumulate the readout request in the corresponding queue (C13). Upon detection of a new MSF in the transmission stand-by buffer **62** in C21, the communication control unit **65** attaches data indicating a lower delay level to the new MSF (C30). When the transmission unit **61** completes the transmission of one MSF in C61, the communication control unit **65** checks whether there exists any MSF in the transmission stand-by buffer **62** (C14), and has the transmission unit **61** convert the first-in MSF therein into the cells and sets the delay level of the first MSF to each (C31). Subsequently, the communication control unit **65** has the transmission unit **61** transmit the resulting cells to the ATM switch **4000** (C32), while resetting the counting value of the first MSF by the request delay timer **64** (C33).

Upon detection of a time-out MSF in the transmission stand-by buffer **62** in C23, a communication control unit **65** attaches the data indicating a higher delay level (C29).

The structure of the ATM switch **4000** in the fifth embodiment will be explained while referring to FIG. 25. The ATM switch **4000** is of the same structure as the ATM switch **4000** in the first embodiment except that it additionally includes a higher priority queue **771** and a lower priority queue **772**. In the drawing, a solid line represents a route of the higher-delay-level cells, and a dashed line represents a route of the lower-delay-level cells.

The higher priority queue **771** accumulates the higher-delay-level cells in the order of arrival, and the accumulated cells are exchanged to be transmitted to their respective destination SCBs in the same order.

The lower priority queue **772** accumulates the lower-delay-level cells in the order of arrival, and the accumulated cells are exchanged to be transmitted to their respective destination SCBs in th same order when no cells are accumulated in the higher priority queue **771**.

The operation of the ATM switch **4000** when transmitting the cells to their destination SCBs (herein SCB **3000**) will be explained while referring to FIG. **26**. In the drawing, INPUT **6*a*** is an input signal to the ATM switch **4000** from the MSFS **1000**, and INPUT **6*b*** is the input signal to the ATM switch **4000** from the MSFS **1001**, while OUTPUT **6*c*** being an output signal from the ATM switch **4000** to the SCB **3000**.

Cells **6*d*1**, **6*d*2**, and **6*d*3** are the lower-delay-level cells stored in the lower priority queue **772** as indicated by the dashed line.

Cells **6*e*1**, **6*e*2**, and **6*e*3** are also the lower-delay-level cells stored in the lower priority queue **772** as are with the Cells **6*d*1**, **6*d*2**, and **6*d*3**.

Cells **6*f*1**, **6*f*2**, and **6*f*3** are the high-delay-level cells stored in the higher priority queue **771** as indicated by the solid line.

In this way, the cells from the transmission unit **61** are stored selectively into either the higher priority queue **771** or lower priority queue **772** depending on their delay level, and transmitted to the SCB **3000** in the order of priority. Thus, the cells **6*f*1**, **6*f*2**, and **6*f*3** are transmitted before the other cells **6*d*1**, **6*d*2**, **6*d*3**, **6*e*1**, **6*e*2**, and **6*e*3** are transmitted.

By controlling the priority at the ATM switch **4000**, the time between the MSF transmission from the MSFSs and the receipt of the MSF by the SCBs can be shortened even when it takes a long time for the transmission unit **61** to transmit the cells (MSFs) to the ATM switch **4000**. As a consequence, the MSFs are received by the SCB at regular intervals even when they are transmitted at different timing from the MSFSs.

The readout delay timer **64** may be activated upon receipt of the readout request to count the delay time, and the priority may be determined based on the delay time.

Sixth Embodiment

In the sixth embodiment, the ATM switch **4000** is replaced with a network **740** consisting of a first ATM switch **741**, a second ATM switch **745**, and a delay monitor **750** as shown in FIG. **27**. The first ATM switch **741** and second ATM switch **745** are connected to each other by a data line **10** (DL**10**), and the delay monitor **750** monitors the cells transmitted via the DL**10**. Note that like in the fourth embodiment, the cells are also discarded by the SCBs in this embodiment.

The delay monitor **750** includes a timer **751** and a monitor control unit **760**.

The timer **751** is of the same structure as the readout delay timer **64** shown in FIG. **10**; however, the timer **751** counts a time between the passing of a readout request sent from the SCB and the passing of the requested MSF; the counted time is referred to as the return time. Also, a time out Tm2 for the timer **751** is determined using Equation 7 as follows in advance.

$$Tm2=Td1-Tf1-Tg1 \qquad (7)$$

where

Tf1 is the minimum delay time between the transmission of the readout request by the SCB and the receipt of the same by the delay monitor **750**; and

Tg1 is the minimum delay time between receipt of the readout request by the delay monitor **750** and the receipt of the requested MSF by the SCB.

The monitor control unit **760** controls the delay monitor **750**, and the operation thereof will be explained while referring to the flowchart in FIG. **28**.

The monitor control unit **760** monitors the cells traveling between the first ATM switch **741** and second ATM switch **745** and a point P**1** on the DL**10**.

When a readout request from the SCB **3000** passes the point P**1** (C**41**, C**42**), the monitor control unit **760** activates the timer **751** to start to count the return time for the readout request (C**43**). Further, upon detection of the requested MSF at the point P**1** (C**42**), the monitor control unit **760** checks whether the timer **751** has counted up the time-out (C**44**). If so, the monitor control unit **760** discards the MSF (C**47**); otherwise it passes the MSF to the destination SCB, resetting the counting value for the MSF (C**46**).

Since the delay monitor **750** discards the MSFs that are likely to be discarded by the SCBs, the load to the ATM switch **4000** can be reduced.

The network **740** may be comprised of more than two ATM switches.

Seventh Embodiment

The video server **100** of the seventh embodiment is of the same structure as the video server **100** of the sixth embodiment except that it discards all the MSFs in the network **740** when the MSF requested by the readout request is judged to be discarded.

For this reason, the monitor control unit **760** detects the sequence number M of the latest MSF and the sequence number M+N of the latest readout request passing through the delay monitor **750**. Also, the monitor control unit **760** counts a time Tm3 between the passing of the latest readout request (M+N) and the passing of the latest MSF (M), and stores a transmission interval Ts between the readout requests.

Thus, the monitor control unit **760** estimates a delay time Tm4 between the passing of the readout request (M) and the passing of the corresponding MSF (M) using Equation 8 as below.

$$Tm4=Tm3+N\cdot Ts-D \qquad (8)$$

where

D is the maximum balance between the readout-request time interval from one subscriber and Ts.

Note that Tm4 thus calculated is the minimum delay time, meaning that there always occurs a least delay of Tm4.

Given Tm4, the monitor control unit **760** discards the MSF (M) when Equation 9 as below is satisfied.

$$Tm4>Td1-Ti1-Tj1 \qquad (9)$$

where

Ti1 is the minimum delay time between the transmission of the readout request from the SCB **3000** and the passing of the same through the delay monitor **750**; and

Tj1 is the minimum delay time between the passing of the MSF through the delay monitor **750** and the receipt of the same by the SCB **3000**.

Thus, the monitor control unit **760** operates as the flowchart in FIG. **29** instead of the flowchart in FIG. **28**.

The monitor control unit 760 monitors the arrival of a readout request from the SCB 3000 at the point P1 (C51). Upon detection of the arrival, the monitor control unit 760 detects the sequence number thereof and activates the timer 751 (C52), and waits for the requested MSF to arrive (C53, C54). Upon receipt of the MSF, the monitor control unit 760 de-activates the timer 751 and obtains the current counting value as Tm3 (C55). Accordingly, the monitor control unit 760 detects the sequence number of the received MSF (C56) to find N by subtracting the MSF sequence number from the readout request sequence number while setting (M) as the MSF sequence number. Further, the monitor control 760 finds Tm4 using Equation 8 (C58), and checks whether Equation 9 is satisfied or not. If Equation 9 is satisfied, the monitor control 760 discards the MSF (C61); otherwise, the monitor control 760 passes the MSF (C60).

By discarding MSFs in estimation, the load to the ATM switch 4000 can be reduced. Also, the MSFs are received at regular intervals even when they are transmitted at different timing.

Eighth Embodiment

In the eighth embodiment, the video server 100 operates depending on a capacity of each queue.

Each MSFS in this embodiment is of the structure shown in FIG. 30, and let the MSFS 1000 be an example. The MSFS 1000 comprises first through K'th queues 71 . . . 7K, a disk array 90 including first through K'th hard disk drives 91 . . . 9K interconnected via a SCSI and readout units 101 . . . 10K, a queue length management unit 110, a dummy request storage unit 120, first through K'th tagged request number storage units 121 . . . 12K, a first-request storage unit 130, a tag attachment unit 135, a selection specification unit 140, an array controller 60, a transmission stand-by buffer 62, and a transmission unit 61. Like components are labeled with like reference numerals with respect to the first embodiment, and the description of these components is not repeated.

The first through K'th queues 71 . . . 7K are of the same structure as the queues 41 . . . 4K in the first embodiment; however, each queue has two predetermined queue lengths (capacities) as an authorization granting threshold and an authorization transferring threshold and stores a dummy request besides the readout requests.

Hereinafter, the readout requests stored in the first queue 71 are referred to as the queue 71's readout requests, and the MSFs readout as per the queue 71's readout requests are referred to as the queue 71's MSFs. Similarly, the readout requests stored in the second and third queues 72•73 are referred to as the queue 72's readout requests and queue 73's readout requests respectively.

The authorization granting threshold is a threshold used to judge whether authorization should be granted to a particular queue, which will be described more in detail while referring to FIGS. 31A and 31B. As was described in the first embodiment, the accumulated readout requests are retrieved from each queue in a predetermined sequence; however, there is a case where it is desirable to give a priority to a specific queue (herein the second queue 72) when it accumulates a large number of readout requests. For this reason, the authorization granting threshold is set in this embodiment in the queue length, so that the authorization will be given to a queue when its queue length exceeds the threshold. In case of FIG. 31A, although a readout request is to be retrieved from the fourth queue 74, the second queue 72 grants the authorization from the forth queue 74; for the second queue 72 accumulates a considerable number of readout request exceeding the threshold.

The authorization transferring threshold is another threshold used to judge whether the authorization should be transferred to a queue having longer queue length. Note that the authorization transferring threshold is set lower than the authorization granting threshold.

The dummy request is the data of the same size as the readout request; it is not used to read out the MSFs but to adjust the length of a queue that has given the authorization to another queue. In case of FIG. 31B, since the fourth queue 74 gives the authorization to the second queue 72, the dummy request is stored in the fourth queue 74 to adjust the length thereof.

The disk array 90 is under the control of the control command in the readout request as was with the disk array 50 of the first embodiment. However, the structure of the hard disk drives 91 . . . 9*k* forming the disk array 90 is different, and let the hard disk drive 91 be an example. The hard disk drive 91 comprises a disk whose memory area is divided into a set of sectors each storing 1024-byte data of the MSF, a disk driving system, a readout head for reading out the data form the sectors, a seek system for seeking the head, a readout unit 101 responsible for the data readout within the hard disk drive 91, a command execution unit for reading out the data from the sectors by controlling the disk driving system and seek driving system, and a cache for temporarily storing the data readout from the sectors.

The operation of the hard disk drive 91 and readout unit 101 will be explained with referring to the flowchart in FIG. 32 detailing the operation of the readout unit 101 and FIG. 33 showing the state diagram of the hard disk drive 91.

The readout unit 101 regularly checks whether the first queue 71 has accumulated a readout request or not (S110). When the queue 71 has accumulated the readout request, the readout unit 101 retrieves the first-accumulated readout request from the first queue 71 (S111), and the queue length management unit 110 decrements the queue length by one to update the length thereof (S112); this will be described more in detail below. Subsequently, the readout unit 101 judges whether the retrieved readout request is dummy or not (S113). In case of a dummy request, the readout unit 101 discards the same (S114) to return to S110, otherwise, the queue length management unit 110 gives a readout direction to the readout unit 101, which delivers the control command contained in the retrieved readout request to the command execution unit (S115), and waits for the requested MSF to be stored in the transmission stand-by buffer 62 (S116).

The MSFs read out from the disk per sector are stored in the cache each time the command execution unit executes the control command (this corresponds to "data readout state α" in FIG. 33). Once the cache receives the requested MSF ("data transmission stand-by state β"), the requested MSF is transmitted to the transmission stand-by buffer 62 ("data transmitting state γ"). When the transmission completes ("available state σ"), the readout unit 101 delivers the retrieved readout request to the first-request storage unit 130 (S117), and waits for the following readout request (S110).

The queue management unit 110 manages the queue length, which will be explained while referring to the flowchart in FIG. 34 using the first queue 71 and hard disk drive 91 as an example.

The queue length management unit 110 monitors the receipt of a readout request for the MSF stored in the hard disk drive 91 (S100). When the receipt is detected, the queue length management 110 refers to the queue length of the first queue 71, where the readout request is to be accumulated, to judge whether the queue length exceeds the authorization granting threshold (S101).

When the queue length has not reached the authorization granting threshold, the queue length management unit 110 has the array controller 60 accumulate the readout request in the first queue 71 (S104); otherwise it directs the tag attachment unit 135 to attach the tag to the readout request (S102). Subsequently, the queue length management unit 110 updates the value in the first tagged-request number storage unit 121 by incrementing the value by one (S103), and has the array controller 60 accumulate the readout request in the first queue 71 (S104). Then, the queue length management unit 110 updates the length of the first queue 71 by incrementing the queue length by one (S105), and waits for the following readout request (S100).

The tag attachment unit 135 attaches the tag to the readout request by establishing an identification area in the readout request to set a distinguishable value therein.

The dummy request storage unit 120 stores the dummy request into the first through K'th queues 71 . . . 7K under the control the selection specification unit 140.

Each of the first through 12K'th tagged-request number storage units 121 . . . 12K holds the number of tagged readout requests.

The first-request storage unit 130 is a memory whose memory area is divided into K sections; K matches with the number of the hard disk drives and queues within one MSFS, and each section includes an identification area. The readout requests processed by the readout units 101, 102, . . . , 10K are written into the K sections respectively, and the state of each hard disk drive is written into the identification area by the corresponding readouts units 101, 102, . . . , 10K.

The selection specification unit 140 refers to the readout request stored in the first-request storage unit 130, and determines which MSF should be transmitted out of the MSFs stored in the transmission stand-by buffer 62 based on the queue length managed by the queue length management unit 110 and the values held in the first through 12K'th tagged-request number storage unit 121 . . . 12K, and directs the transmission unit 61 to transmit the determined MSF. The operation of the selection specification unit 140 will be explained while referring to the flowchart in FIG. 35. In the drawing, k and j (k is not equal to j) are the variables that specify the queues and tagged-request number storage units within one MSFS.

The selection specification unit 140 retrieves a readout request identified by a predetermined sequence number from the first-request storage unit 130, and specifies the queue (k'th queue) that had stored the readout request (S120). Further, the selection specification unit 140 checks whether the k'th queue stores any tagged readout request using the value in the k'th tagged-request number storage unit 12*k* (S200). When the k'th queue stores the tagged readout request, the selection specification unit 140 has the transmission stand-by buffer 62 transmit the MSF corresponding to the k'th queue to the transmission unit 61 (S201). Accordingly, the transmission unit 61 judges whether the readout request is attached with a tag or not (S202). In case of a tagged readout request, the selection specification unit 140 decrements the value in the k'th tagged-request number storage unit 12*k* by one; for the number of the readout requests requiring a transmission process time has decreased (S203). Then, the selection specification unit 140 waits until the transmission unit 61 completes the transmission (S204), and retrieves the following readout request (S120).

As a result, the MSF read out as per the readout request arriving at the request receipt unit 31 first is transmitted to the request sender SCB (herein 3000) from the hard disk drive 91. But transmitting the MSF corresponding to the k'th queue first, the delay time caused in reading out the requested MSF can be compensated.

When the value in the k'th tagged-request number storage unit 12*k* exhibits "0", or the k'th queue stores no tagged request in S200, the selection specification unit 140 checks whether the k'th queue's length exceeds the authorization transferring threshold or not (S205). When the queue length exceeds the authorization transferring threshold, the selection specification unit 140 judges that the k'th queue still stores a number of requests, and accordingly has the transmission stand-by buffer 62 transmit the MSF corresponding to the k'th queue to the transmission unit 61 (S201). Then, the selection specification unit 140 judges whether the readout request that has readout the MSF corresponding to the k'th queue is attached with the tag or not (S202). In case of a tagged readout request, the selection specification unit 140 decrements the value in the k'th tagged-request number storage unit 12*k* by one (S203); for the number of the readout requests has decreased. Otherwise, the selection specification unit 140 leaves the value in the k'th tagged-request number storage unit 12*k* intact. When the queue length has not reached the authorization transferring threshold in S205, the selection specification unit 140 checks whether the first-request storage unit 130 stores the request of the other queues (S206). When the first-request storage unit 130 stores the request of the other queues, the selection specification unit 140 refers to such request (the j'th queue's request) (S213), and checks whether the value in the j'th tagged-request number storage unit 12*j* exhibits "0" (S207). When the value does not exhibits "0", the selection specification unit 140 has the transmission stand-by buffer 62 transmit the MSF corresponding to the j'th queue to the transmission unit 61 (S209).

In this way, the MSF corresponding to the j'th queue is transmitted before the MSF corresponding to the k'th queue, and thus the selection specification unit 140 has the k'th queue accumulate the dummy request to prolong the length thereof (S210). Then, the selection specification unit 140 judges whether the readout request that has read out the MSF corresponding to the j'th queue is attached with the tag or not (S211). In case of a tagged readout request, the selection specification unit 140 decrements the value in the j'th tagged-request number storage unit 12*j* by one (S212); for the number of the readout requests has decreased. Otherwise, the selection specification unit 140 leaves the value in the j'th tagged-request number storage unit 12*j* intact.

Subsequently, the selection specification unit 140 waits for the transmission unit 61 to complete the transmission (S204), and retrieves the following readout request from the first-request storage unit 130, and repeats the above-described operation (S120).

By giving a higher priority to a queue storing a larger number of readout requests, the delay times between the receipt of the readout requests and the transmission of the requested MSFs vary in a small range. In addition, since the hard disk drives with a low transmission rate can be used, the manufacturing cost can be saved.

The dummy request storage unit 120 stores one dummy request under the direction of the selection specification unit 140, and the queue length is incremented by one in this embodiment; however, the dummy request storage unit 120 may store more than one dummy request and the queue length may be incremented by one fifth or five for one dummy request.

Ninth Embodiment

In the ninth embodiment, in addition the operation of the eighth embodiment, the time required to transmit the requested MSF is compared based on the queue length to determine from which queue the request should be transmitted.

Accordingly, each MSFS in the ninth embodiment additionally includes a plurality of delay value hold units **141** . . . **14K** and excludes the dummy request storage unit **120** as shown in FIG. **36**.

The delay value hold unit **141** . . . **14K** correspond to the queues **71** . . . **7K** respectively, and each hold the delay value of their respective queues and an authorization transferring threshold. The delay value referred herein is the sum of the process time required at each readout unit and the transmission time required at the transmission unit **61** multiplied by the number of the requests stored in the corresponding queue. The delay value is periodically computed and if the request is larger than the value held in the corresponding delay value hold unit, the latter is updated with the former.

The operation of the queue length management unit **110** in this embodiment will be explained while referring to the flowchart in FIG. **38**. Since the flowchart in FIG. **38** is partly identical with the flowchart in FIG. **34**, only the different steps will be explained.

After **S105**, the queue length management unit **110** estimates the process time using the first queue **71**'s length (**S106**), and judges whether the estimated process time exceeds the value held in the corresponding delay value hold unit **141** (**S107**). When the former exceeds the latter, the queue length management unit **110** updates the latter with the former (**S108**). In this way, the delay value is updated each time the queue accumulates a readout request.

Because the dummy request storage unit **120** is excluded in this embodiment, each readout unit operates by following the flowchart in FIG. **37** instead of FIG. **32**. Since two flowcharts are partly identical, only the different steps will be explained.

After **S112**, the readout unit **101** proceeds to **S115** and onwards. When the first queue **71** does not accumulate any readout request in **S110**, the corresponding readout unit **101** resets the value in the delay value hold unit **141** to "0" (**S118**), and returns to **S110**.

Also, the selection specification unit **140** operates by following the flowchart in FIG. **39** instead of the flowchart in FIG. **35**. Since two flowcharts are partly identical, only the different steps will be explained.

When the number of tags in the k'th queue exhibits "0" in **S200**, the selection specification unit **140** checks whether the delay value exceeds the authorization transferring threshold or not (**S300**). When the former exceeds the latter, the selection specification unit **140** proceeds to **S201** and transmits the MSFs corresponding to the k'th queue 7*k* until the former falls below the latter; otherwise it proceeds to **S206**.

When the selection specification unit **140** directs the transmission unit **61** to transmit the MSF corresponding to the j'th queue in **S209**, the selection specification unit **140** updates the value in the delay value hold unit 14*k* (**S301**), and proceeds to **S211**. The amount of update equals to the waiting time caused by giving the k'th queue a lower priority, making the delay value in the delay value hold unit 14*k* larger. Thus, it becomes easy for the delay value to exceed the authorization transferring threshold.

As a result, the delay times between the receipt of the readout requests and the transmission of the requested MSFs vary in a small range. In addition, since the hard disk drives with a low transmission rate can be used, the manufacturing cost can be saved.

The waiting time until the MSFs are transmitted by the transmission unit **61**, or namely a waiting time between the completion of the MSF readout and the transmission of the same, may be added to the delay value.

The selection specification unit **140** selects the request in the first-request storage unit **130** in the order of arrival at the request receipt unit **31** in the eighth and ninth embodiments. However, a counter may be additionally included, so that the readout units **101**, **102**, **103** . . . may be referred to either cyclic or at random each time the counter counts one. Also, the readout units may be referred to in the order of the time from the last reference, or the corresponding queue's length.

The tags are attached by varying the value in the additionally established identification areas in the eight and ninth embodiments. However, when there is an available area in the readout request, the tags may be attached using such available area.

Tenth Embodiment

In the tenth embodiment, a plurality of terminals are connected to one SCB. Thus, each terminal sends a request signal (hereinafter referred to as second data request) As shown in FIG. **40**, the second data request comprises identification data (USR) identifying individual terminal, program data (INF) for a desired program, the value (VAB) of a mean data receipt rate of the terminals. USR is attached to the readout requests and MSFs to identify the request-sender terminal.

FIGS. **41** and **42** are the views depicting the structures of the SCBs and MSFSs in this embodiment respectively, and let the SCB **3000** and MSFS **1000** be examples.

The SCB **3000** comprises a second-data-request receipt unit **201**, a timer **202**, a minimum-issuance-interval hold unit **203**, an issuance time management unit **204**, a first-data-request transmission judgment unit **205**, a first-data-request transmission unit **206**, an MSF distribution unit **207**, and a request issuance time hold unit **208**.

The second-data-request receipt unit **201** receives the second data requests and notifies the receipt of the same, which will be explained while referring to the flowchart in FIG. **43**.

The second-data-request receipt unit **201** regularly checks whether any second data request has arrived from the terminals (R11) to notify the values of USR and VAB to the issuance time management unit **204** upon the receipt thereof (R12), while notifying the values of INF and USR to the first-data-request transmission judgment unit **205** (R13), and waits for the following second data request (R11).

The timer **202** exhibits a current time.

The minimum issuance interval hold unit **203** computes and stores the minimum issuance interval of the first data requests sent from the SCB **3000**. The minimum issuance interval is computed by multiplying VAB in the second data request by the number of the terminals connected to the SCB **3000** and dividing the result by the size of the data issued accompanying with the issuance of the first data request.

FIG. **44** is the format of the first data request. The first data request corresponds to the readout request in the first embodiment. For this reason, in the first data request, USR is attached to each MSFP which is referred to as ADD hereinafter.

The issuance time management unit **204** computes the issuance interval between the first data requests, and makes out a schedule for the issuance of the first data requests to all the connected terminals. The issuance time management unit **204** includes a buffer (not shown) to store one scheduled time coming next (next issuance time) from the current time.

The explanation of how the issuance time management unit **204** makes out the schedule will be explained while referring to FIGS. 45A, 45B, and 45C. In this example, let the issuance interval be 40, and minimum issuance interval be 5.

In FIG. 45A, "1", "41", "81", "121" and "161" in the scheduled time column are the scheduled times when the first data requests are issued from the terminal usr1. Although the column ends at "161", the issuance time management unit **204** adds "201", "241", "281", . . . as the time elapses.

When the terminal usr4 issues a second data request at "1", the issuance time management unit **204** makes out a schedule for the terminal usr4 at the minimum issuance intervals "5", that is to say "6", "46", "86", "126" as shown in FIG. 45B.

Similarly, when the terminals usr2, usr3, and usr5 issue the second data requests at "1", the issuance time management unit **204** makes out the schedules at the minimum issuance intervals "5" for each, that is to say, "1", "6", "11", "16", "21", . . . for the terminals usr1, urs4, usr2, usr3, usr5 respectively as shown in FIG. 45C.

The operation of the issuance time management unit **204** will be explained while referring to the flowchart in FIG. 46.

The issuance time management unit **204** waits for the next issuance time with referring to the timer **202** (E11), during which it checks the receipt of the second data request (E12). Upon the detection of the receipt in E12, the issuance time management unit **204** computes the mean issuance interval between the first data requests for each user (E13), and store the same (E14). Accordingly, the issuance time management unit **204** makes out a schedule for the first data requests based on the mean interval and minimum issuance interval (E15). Note that when the balance between the mean issuance interval and actual issuance interval is larger than a predetermined value, the issuance interval is shortened.

When there is no second data request in E12, the schedule is updated by adding the following scheduled times as the time elapses (E15).

Having made out the schedule, the issuance time management unit **204** checks whether there is any scheduled time before the next issuance time in the buffer to retrieve and store the same in the buffer (E16, E17, and E18). When there is no next issuance time in the buffer, the issuance time management unit **204** stores the scheduled time in the buffer, and waits for another next issuance time (E11).

On the other hand, when the issuance time management unit **204** judges that it is the next issuance time in E11, it directs the first-data-request transmission judgement unit **205** to issue the first data request (E19), and has the issuance time hold unit **208** hold the issuance time (E20). Subsequently, the issuance time management unit **204** stores the following scheduled time in the buffer (E21), and waits for another next issuance time (E11).

The first-data-request transmission judgment unit **205** directs the first-data-request transmission unit **206** to transmit the first data request as per the direction by the issuance time management unit **204**.

The operation of the first-data-request transmission judgment unit **205** will be explained while referring to the flowchart in FIG. 47.

Upon receipt of the values of USR and INF from the second-data-request receipt unit **201** (J10), the first-data-request transmission judgment unit **205** retrieves ADDs for the specified terminal from the SCF storage unit **10** in the SM **2000**, and stores the retrieved MSFPs as ADDs with the corresponding USR in the form of a corresponding table (J11). In this way, the first-data-request transmission judgment unit **205** stores the values of USR, INF and ADD each time the receipt of the second data request is notified.

On the other hand, when the first-data-request transmission judgment unit **205** is notified that it is the next issuance time by the issuance time management unit **204** (J12), it judges whether the correspondence table has been obtained or not (J13).

When the correspondence table has not been obtained yet, the first-data-request transmission judgment unit **205** returns to J10; otherwise, it retrieves the values of USR and ADD corresponding to the next issuance time from the correspondence table to generate the first data request and directs the transmission of the same to the first-data-request transmission unit **206** (J14). Then, the first-data-request transmission judgment unit **205** waits for the notice of the following values of USR and INF and transmission direction (J10, J12).

The first-data-request transmission unit **206** transmits the first data requests to the MSFSs **1000, 1001, 1002**, . . . under the direction of the first-data-request transmission judgment unit **205**.

The operation of the first-data-request transmission unit **206** and the second-data-request receipt unit **201** will be explained while referring to FIGS. 48, 49A, and 49B.

As shown in the timing chart in FIG. 49A, when the second-data-request receipt unit **201** receives the second data requests at irregular intervals, the issuance time management unit **204** transmits the same under the direction of the first-data-request transmission judgment unit **205**, which receives the transmission direction for every transmission interval and minimum transmission interval (T10). Thus, the first-data-request transmission unit **206** transmits the first data requests for every minimum issuance interval T as shown in FIG. 49B. For this reason, when the second data requests are issued in burst, still the first data request can be transmitted at regular intervals (T11). After the first-data-request transmission, the issuance time management unit **204** waits for the following transmission direction (T10).

The MSF distribution unit **207** includes a buffer memory **210** and receives the MSFs transmitted from the MSFSs **1000, 1001, 1002**, . . . as per the first readout requests sent from the first-data-request transmission unit **206**, stores the same into the buffer memory **210**, and further transmits the MSFs in the buffer memory **210** to the request-sender terminal, which will be explained while referring to the flowchart in FIG. 50.

The MSF distribution unit **207** monitors the transmission of MSFs and arrival of the transmission time (D10, D12). Upon receipt of MSFs from any of the MSFSs **1000, 1001, 1002**, . . . , the MSF distribution unit **207** receives the same (D10) and stores the same into the buffer memory **210** (D11); otherwise, it waits for the MSFs.

Subsequently, the MSF distribution unit **207** refers to the timer **202** to check whether it is the time to transmit the

MSFs (D12). When it becomes the right time, the MSF distribution unit 207 judges whether the buffer memory 210 stores any MSF (D13), and identifies the request-sender terminal using the value of USR attached thereto (D14), sending the MSF to the identified request-sender terminal (D15). Subsequently, the MSF distribution unit 207 resumes the monitoring the transmission of MSFs and arrival of the transmission time (D10, D12).

The request issuance time hold unit 208 stores the time when the direction of the issuance of the first data request was given last.

Next, the MSFS 1000 in the tenth embodiment will be explained. As is shown in FIG. 42, the MSFS 1000 comprises a first-data-request receipt unit 301, a data transmission interval hold unit 302, a timer 303, a data readout.transmission control unit 304, data-cluster-transmission directing time hold unit 305, a transmission unit 306, the disk array 50 including the hard disk drives 51 . . . 5K.

The disk array 50 in this embodiment is of the same structure in the first embodiment; however, it stores the MSFs in the form of data clusters. The data cluster referred herein is a storage unit of the same data size as the MSF.

Each data cluster includes identification data called a PLS value. The hard disk drives 51 . . . 5K store the SCSI number of the disk storing the MSF, disk number, and the logical block number indicating the MSF storage location in the PLS value.

The data request receipt unit 301 receives the first data requests sent from the SCB 3000, 3001, 3002, . . . , and notifies the values of USR and ADD contained therein to the data readout.transmission control unit 304, which will be described more in detail while referring to the flowchart in FIG. 51.

The data request receipt unit 301 checks regularly whether the first data request is received or not (R10). When the first data request is received, the first-data-request receipt unit 301 notifies the values of the USR and ADD contained therein to the data readout.transmission control unit 304 (R11, and waits for the following readout request (R10).

The data transmission interval hold unit 302 holds the interval between the data transmission within one data cluster. The data transmission interval in this embodiment is found by dividing the mean value of the arrival times of the first data readout requests addressed to one MSF by the number of the data clusters.

The transmission interval held in the data transmission interval hold unit 302 is referred to as data transmission time together with the transmission directing time held in the data-cluster-transmission directing time hold unit 305.

The timer 303 counts the time.

The data readout.transmission control unit 304 manages the data related to the data clusters of the readout requests, and controls the readout and transmission of the data based on the received first data requests, which will be explained more in detail while referring to the flowchart in FIG. 52.

The data readout.transmission control unit 304 checks whether the values of USR and ADD are notified from the first-data-request receipt unit 301, or it is the data transmission time (C60, C64). When the values of USR and ADD are notified from the first-data-request receipt unit 301, the data readout.transmission control unit 304 stores the same (C60, C61), and retrieves the PLS value in the data cluster from the ADD value to store the same (C62, C63). The hard disk drives 51 . . . 5K store the SCSI number for the disk storing the MSF, and the disk number, and the logical block number in relation with the value of PLS. The SCSI, disk, logical block numbers are included in the ADD value (MSFP), and thus, when the data transmission time comes (C64), the data readout.transmission control unit 304 successively reads out the MSFs as per the data clusters corresponding to the readout requests, and directs the transmission unit 306 to transmit the MSFs. In so doing, the data readout-transmission control unit 304 notifies the values of the data clusters and USR specifying the destination to the transmission unit 306 (C65). Subsequently, the data readout.transmission control unit 304 refers to the timer 303 (C66), and has the data-cluster-transmission directing time hold unit 305 store the transmission time when the readout and transmission of the MSFs are directed (C67), and waits for the following notice of the values of USR and ADD, and the arrival of the following transmission time (C60, C64).

The transmission unit 306 retrieves the data from the respective hard disk drive under the direction of the data readout.transmission control unit 304 to transmit the same to the SCB (herein 3000), which will be detailed by the flowchart in FIG. 53.

The transmission unit 306 waits for the transmission direction from the data readout-transmission control unit 304 (T70). When the transmission direction arrives, the transmission unit 306 receives the MSFs read out by the data readout-transmission control unit 304 to transmit the same to the ATM switch 4000 (T71).

By transmitting the first data requests at regular intervals longer than the minimum issuance interval, the requests and MSFs will not be transmitted intensively. As a result, the traffic jam within the ATM switch 4000 will be mitigated, upgrading the efficiency of the ATM switch 4000.

The minimum issuance interval may be shortened when the number of the first data requests waiting to be transmitted exceeds a predetermined threshold.

The second data request may be formatted differently from the example in this embodiment as long as the identification data identifying the request data, and the destination of the MSFs are included.

Also, the first data request may be formatted differently form the example in this embodiment as long as the identification data identifying the request-sender SCB and the logical address specifying the storage location of the requested MSF are included.

The order of the arrival of the second data requests may be stored to issue the corresponding first data requests at minimum issuance intervals.

Although the data cluster is used as a memory unit of the MSF, other units can be used as long as the MSF's storage location can be specified.

The buffer memory monitor unit 22 in the first embodiment may be installed between the buffer memory 210 and first-data-request transmission unit 206 to transmit the first data requests depending on the available capacity of the buffer memory 210.

Eleventh Embodiment

In the eleventh embodiment, when a plurality of SCBs sends out the readout request to one MSF, the MSF are copied in the matching number.

Thus, ATM switch 4000 is connected to a copy unit 6000 as shown in FIG. 54.

The copy unit 6000 copies the data in the cells in accordance with a copy list to transmit the resulting cell copies to their respective destinations. The copy list referred herein is a list of the destinations for each cell copy, and generated by the MSFs. The cell-copy technique is detailed in U.S. Pat. No. 5,287,530 issued on Feb. 15, 1994, and the further explanation is omitted herein.

To make the cell copies, the array controller 60 operates by following the flowchart in FIG. 55 instead of FIG. 11B; for the array controller 60 in this embodiment includes a flag register, and sets a flag F in accordance with each readout request accumulated in the queues.

The array controller 60 monitors the arrival of a readout request regulariy (S3301). Upon detection of the readout request, the array controller 60 judges whether the corresponding hard disk drive is reading out the MSFs (S3302). When the hard disk drive is not reading out the MSFs, the array controller 60 outputs the readout request to the hard disk drive (S3303). While the hard disk is reading out MSFs, the array controller 60 monitors the arrival of the following readout request (S3301). When the following readout request arrives, the array controller 60 inquires the corresponding hard disk drive whether it has completed the MSF readout (S3302). When the hard disks is still reading out the MSFs, the array controller 60 discriminates the MSF corresponding to the readout request, and judges whether any readout request for the same MSF has been accumulated in the corresponding queue (S3307). When such readout request has been accumulated in the queue, the array controller 60 sets the flag F of the readout request to "1" and accumulates the readout request in the queue (S3308).

On the other hand, when there is no readout request for the same MSF, the array controller 60 accumulates the readout request in the queue, setting the flag F of the readout request "0" (S3309).

Having set the flag F, the array controller 60 resumes the monitoring of the arrival of another readout request (S3301), and waits the hard disk drive to complete the MSF readout (S3305, S3304).

When the hard disk drive completes the MSF readout, the array controller 60 checks whether there is any readout request accumulated in the queue (S3306) to retrieve the first-accumulated readout request therein, and judges whether the flag F of the retrieved readout request is set to "1". When the flag F is set to "1", the array controller 60 retrieves the readout requests requesting the same MSF from the queue to generate the copy list (S3313). Then, the array controller 60 transmits the copy list thus generated to the copy unit 6000, and deletes the readout requests on the list from the queue, cutting the queue length shorter. Having deleted the retrieved readout requests, the array controller 60 reads out the MSF as per the readout request from the hard disk drive, transmitting the same to the copy unit 6000 (S3314).

The copy unit 6000 receives the copy list and MSF converted into the cells, and copies the MSF in a matching number with the number of the readout requests on the copy list. Having copied the cells (MSF), the copy unit 6000 varies the addresses on the copy list into the cells separately, and outputs the same to the ATM switch 4000. The cell copies (MSF copies) outputted to the ATM switch 4000 are delivered to their respective request-sender SCBs.

By copying the cells (MSF) and sending the same when a plurality of readout requests are sent to one particular MSF at a time, the requested MSF can be transmitted to their respective request sender SCBs simultaneously, speeding up the MSFS's operation.

TwelftH Embodiment

In the twelfth embodiment, the MSFSs also serve as the copy unit 6000.

Thus, the communication control unit 65 includes an MSF transmission management table as shown in FIG. 56.

The MSF transmission management table is used to dived the received readout requests into groups for each MSF, and consists of entries including three columns: a requested MSF identification number, a destination, and a list of other destinations.

The requested MSF identification number column exhibits the MSP sequence numbers identifying the individual MSFs requested by the readout requests, which was mentioned in the first embodiment. The destination column exhibits the address of the SCB which has sent the readout request to one particular MSF first. The other destination list column exhibits the addresses of the other SDBs that have sent the readout request to the same MSF second and onwards.

For example, from left to right in the top of the MSF transmission management table, "2130" is the identification number of one MSF, "1" is the address of the SCB that has sent the readout request to the MSF identified as "2130", and "10" is the address of the SCB that has also sent the readout request to the same MSF following the SCB "10".

In addition to the function described in the first embodiment, the communication control unit 65 operates by following the flowcharts in FIGS. 57 and 58, which will be explained in the following with referring to FIG. 56 as well.

When the request receipt unit 31 receives a readout request (S1001), the communication control unit 65 checks whether the identification number of the MSF requested by the readout request is listed on the MSF transmission management table (S1002). Assume that the SCB 3004, whose address is "5", has requested the MSF identified by "2130" (S1003), then the communication control unit 65 writes the address "5" in the other destination list of the MSF "2130" in the MSF transmission management table. (S1004).

When there is no corresponding MSF in the MSF transmission management table in S1003, the communication control unit 65 adds a new entry by writing the address of the requested MSF and its destination (S1005, S1006).

When there is any MSF in the transmission stand-by buffer 62 (S1102 in FIG. 58), the communication control unit 65 selects the first-in MSF therein (S1102) to send the same to the request-sender SCB (S1103). Having transmitted the first-in MSF, the communication control unit 65 checks whether the identification of the transmitted MSF is listed on the MSF transmission management table (S1104). If so, the communication control unit 65 retrieves all the addresses in the other destinations list column to copy the transmitted MSF for the number of the retrieved addresses (S1109), writing the retrieved addresses into the MSF copies separately (S1110).

In case of FIG. 56, the transmission stand-by buffer 62 stores the MSF identified by "6521". Then, the communication control unit 65 retrieves the addresses "1" and "3" from the MSF transmission management table, makes two copies of the MSF, writes the addresses "1" and "3" in the MSF copies respectively, and has the transmission unit 61 transmit the MSF copies (S1111). Subsequently, the communication control unit 65 deletes the transmitted MSF from the transmission stand-by buffer 62, and the entry thereof in the MSF transmission management table as well (S1107, S1108).

By copying the MSF and sending the same, the requested MSF can be transmitted to their respective request sender SCBs when a plurality of readout requests are sent to one particular MSF, upgrading the operating speed of the MSFS.

Thirteenth Embodiment

In the thirteenth embodiment, the SCF of the requested video are obtained partially.

Thus, the MSFP transmission control 23 includes a partial-SCF buffer (not shown) instead of the SCB buffer, and an SCF obtainment control unit (not shown) instead of the selection signal separation unit 20 for monitoring an available capacity of the partial-SCF buffer to retrieve SCF from the SM 2000 according to the available capacity.

The operation of the SCF obtainment control unit will be explained while referring to the flowchart in FIG. 59.

The SCF obtainment control unit regularly monitors whether the MSFP transmission control unit 23 transmits an SCB obtainment request (S1301). Upon detection of the SCF obtainment request, the SCF obtainment control unit requests the transmission of 10-minute long MSFPs out of the corresponding SCF to the SM 2000 (S1302). Upon receipt of the MSFPs, the MSFP transmission control unit 23 generates the readout request using the MSFPs, and transmits the same to the corresponding MSFSs (S1303).

Also, the SCF obtainment control unit regularly monitors a playback mode request (S1304). Upon detection of the playback mode request, the SCF obtainment control unit determines the remaining level to the playback mode (S1305); otherwise, the SCF obtainment control unit continues the monitoring, leaving the current remaining level intact (S1306).

The remaining level referred herein is a threshold used to determine whether the following partial SCF should be requested by judging the amount of the partial-SCF buffer. Assume that 10% is the remaining level for the normal playback mode, then the SCF obtainment control unit requests the following partial SCF when the remaining MSFPs in the partial-SCF buffer becomes 10% of the capacity thereof. Similarly, assume that 30% is the remaining level for the fast playback mode, then the SCF obtainment control unit requests the following partial SCF when the remaining level of the MSFPs in the partial-SCF buffer becomes 30%, and assume that 3% is the remaining level for the slow playback mode, then the SCF obtainment control unit requests the following partial SFC when the remaining level of the MSFPs in the partial-SCF buffer becomes 3%.

Having set the remaining level, the SCF obtainment control unit checks whether the remaining MSFPs is less or more than the remaining level (S1307). When the former is less than the latter, the SCF obtainment control unit requests the transmission of the following partial SCF (S1308).

Further, the SCF obtainment control unit checks the last MSFP in the SCF (S1309). If the last MSFP is not included, the SCF obtainment control unit resumes the monitoring on the playback mode (S1304); otherwise, it waits for another SCF obtainment request (S1301).

Since the SCB stores the SCF partially, a considerably long SCF can be stored in the SCF buffer with a small capacity.

The charge management unit 13 may detect how many MSFPs in one SCF are retrieved, so that the charges become directly proportional the length of the video transmitted to the terminal.

Fourteenth Embodiment

In the fourteenth embodiment, the video stored in the MSFSs, 1000, 1001, 1002 are re-written. Thus, the video server 100 in this embodiment is installed at the CATV station, and connected to the video players within the station.

The structure of a system using the video server 100 in the fourteenth embodiment is shown in FIG. 15.

The system controls all the units in the station, and comprises a total system manager (TSM) 910 responsible for the control of the transmission route between the terminals and video server 100 as well as the management of the charges and programs, an encoder 920 for converting a video signal into the MPEG 2 format, and a transmission unit 940 for converting an analog signal from a conventional analog broadcast unit 930 into a digital signal to multiplex the same.

FIG. 60 depicts the structure of the SM 2000 in this embodiment. The SM 2000 includes an available area management unit 12 and an available area sequence data notice unit 15 in addition to the structure shown in FIG. 5.

The available area management unit 12 manages overwritable areas within the memory area of the MSFSs 1000, 1001, 1002, . . . as recordable areas. The data related to the available areas are used for such management; the data related to the available areas are used as a pointer for the overwritable area, and contain an area identifier, the address of the corresponding MSF, and location of the available area in the disk array 50 in the MSFS. Thus, the available area data are of a similar structure as the MSFP shown in FIG. 4 except that they additionally include the area identifier and that a "write" command is assigned. The available area data include the parameters for the write command to the disk array, and thus they also serve as a disk control command to write the data by accessing to the disk array.

The available area sequence data notice unit 15 accepts a record request, edits a write control file (WCF) for the video to be recorded in the available area, sending the WCF to the request-sender SCB. To be more specific, upon receipt of the record request, the available area sequence data notice unit 15 align the available area data for each MSFS in a predetermined sequence: the available area data related to the MSFS 1000 is placed first, and the available area data related to the MSFSs 1001 and 1002 are placed second and third respectively. Having aligned the available area data, or edited the WCF, the available area sequence data notice unit 15 transmits the WCF to the FD 5000, so that it converts the WCF into an SCF to have the SCF storage unit 10 store the same for the recorded video.

The recording operation will be explained while referring to the timing chart in FIG. 16.

Prior to the video writing, the TSM 910 has the available area sequence data notice unit 15 in the SM 2000 generate the WCF for the video by outputting a WCF generation request (WCF_Create_Req) to the SM 2000.

When the SM 2000 receives the generation request, the available area sequence data notice unit 15 edits the WCF in the period indicated by (New_WCF_Create), transmitting the WCF to the TSM 910 as a request response (WCF_Create_Rsp). Upon receipt of the WCF, the TSM 910 outputs a record start request (Start) to the FD 5000, which in turn outputs a WCF obtain request (WCF_Get_Req) to the available area sequence data notice unit 15, and the available area sequence data notice unit 15 transmits the WCF to the FD 5000 as a request response (WCF_Get_

Rsp). Accordingly, the FD 5000 outputs a record start request (Start) to the encoder 920 by means of the TSM 910. The encoder 920 then outputs the 64-byte image data to the FD 5000, which converts the same into the MSF. Further, the FD 5000 generates a record request (MSF_Write_Req(1)) to write the first MSF using the available area data placed first in the WCF, outputting the same to the request-sender MSFS 1000 (MSFS[1]) together with the corresponding MSF. Since the record request also serves as the write control command to the disk array 50, the MSF is written into the disk array 50 within the period indicated as (MSF Record). Subsequently, the MSFS 1000 transmits a record completion notice (MSF_Write_Rsp(1)) to the FD 5000, which in turn receives the following 64-Kbyte image data from the encoder 920 and generates another record request (MSF_Write_Req(2)) to write the second MSF using the second available area data, and sends the same to the request-sender MSFS 1001 (MSFS[2]) together with the corresponding MSF.

FIG. 61 depicts the structure of each MSFS of the fourteen the embodiment, which additionally includes a write request queue 410 and an MSF buffer 411 compared with the MSFSs in the first embodiment.

The write request queue 410 holds the write requests sent to its MSFS, and the write requests are processed in the order of arrival when all the readout requests in the queues 41, 42, 43, . . . have been processed.

The MSF buffer 411 holds the MSFs transmitted to its MSFS and the MSFs are retrieved by the array controller 60 to be stored in the disk array 50.

The communication control unit 65 in this embodiment operates by following the flowcharts in FIGS. 13 and 62.

The communication control unit 65 checks the receipt of a readout request, a write request, and cells (MSF), and whether there is any readout request in the queue furnished for the hard disk drive to which the write request is addressed (C10 in FIG. 13, C81, C82, and C83 in FIG. 62). Upon receipt of the write request in C81, the communication control unit 65 accumulates the same in the write request queue 410 (C84). Upon receipt of the cells (MSF) in C82, the communication control unit 65 stores the same into the MSF buffer 411 (C85).

When all the readout requests in the queue furnished for the write request's addressing hard disk drive have been processed in C83, the communication control unit 65 successively outputs the write requests in the write request queue 410 to the array controller 60, and has the array controller 60 retrieve and store the MSF in the MSF buffer 411 into the disk array 50.

As has been stated, each MSFS in this embodiment can rewrite the video stored therein when there is no readout requests. For this reason, the video can be written while reading out the video at real time.

Only a single write request queue is furnished in this embodiment; however, it may be furnished for each hard disk drive.

In the first through fourteenth embodiments, MSFs are stored in the hard disk drives; however, they may be stored other storing media such as memory, optical disks, and video tapes.

Although the present invention has been fully described by way of examples with reference to the accompanying drawings, it is to be noted that various changes and modifications will be apparent to those skilled in the art. Therefore, unless otherwise such changes and modifications depart from the scope of the present invention, they should be construed as being included therein.

What is claimed is:

1. A video server which transmits digital video data comprising frame blocks having a predetermined sequence and stored therein to subscriber terminals as per video requests comprising:

a plurality of frame block servers, each including a computer interface unit, an image memory and a readout control unit for the image memory, each image memory storing a plurality of said frame blocks non-consecutive with respect to said predetermined display sequence, the readout control unit receiving readout requests and in response reading out requested frame blocks from the image memory;

management means for storing management data specifying which frame block server stores which frame block in the image memory;

a plurality of subscriber interfaces for receiving the video requests from the subscriber terminals, and in response sending readout requests to the frame block servers to readout the frame blocks forming requested digital image data in the predetermined sequence while referring to the management data, and for transmitting the frame blocks transmitted from the frame block servers to the subscriber terminals at such timing that ensures continuous play; and

exchange means for interconnecting each block server and each subscriber interface to transfer the frame block servers as per the readout requests to the request-sender interfaces.

2. The video server of claim 1, wherein the management data comprise a plurality of block pointers, each identifying a location of each frame block respectively, and including an address of each frame block server that stores each frame block respectively, and

wherein each subscriber interface includes:

a management data obtainment unit for receiving the video request from the subscriber terminal, and in response retrieving block pointers for the requested piece of digital video data from the management means;

a readout request generation unit for generating a readout request for each retrieved block pointer addressing to the frame block server specified by the address included therein;

a readout request transmission unit for transmitting the readout requests to the specified frame block servers, one readout request being transmitted at a time; and

a frame block output unit for receiving the frame blocks read out as per the readout requests, and in response outputting the frame blocks to the request-sender subscriber terminal at predetermined timing.

3. The video server of claim 2, wherein each subscriber interface further includes an estimated return time storage unit for storing an estimated time between a transmission of the readout request and a receipt of the requested frame block as an estimated return time, the estimated return time varying depending on a frame-block readout rate of the frame block server, an exchange ability of the exchange means, and a transmission rate of the subscriber interface in transmitting the requested frame block to the subscriber terminal, and

wherein the readout request transmission unit transmits the readout requests at an interval equal to the estimated return time before the frame block output unit outputs the requested frame blocks at the predetermined timing.

4. The video server of claim 3, wherein each subscriber interface further includes:

a return time counter for counting an actual time required to transmit the readout request and receive the requested frame block; and

a balance computation unit for computing a balance between the actual time and the estimated return time, and

wherein the readout request transmission unit includes a transmission control unit for controlling a readout-request transmission in such a way that the readout requests are transmitted at an interval equal to the balance before the predetermined timing.

5. The video server of claim 4, wherein the estimated return time storage unit stores the estimated return times for each frame block server, and

wherein the return time counter counts the actual times for each frame block server, and

wherein the balance computation unit computes the balances for each frame block server, and

wherein the transmission control unit controls a readout-request transmission in such a way that the readout requests are transmitted to their respective specified frame block servers before the predetermined timing while referring to the balance for the frame block servers.

6. The video server of claim 3, wherein each subscriber interface further includes:

a return time counter for counting an actual time required to transmit the readout request and receive the requested frame block; and

a return time update unit for updating the estimated return time stored in the estimated return time storage unit with the actual time counted by the return time counter, and

wherein the readout request transmission unit transmits the readout requests at an interval before the frame block output unit outputs the requested frame block at the predetermined timing, the interval being equal to the updated estimated return time.

7. The video server of claim 6, wherein the estimated return time storage unit stores the estimated return times for each frame block server, and

wherein the return time counter counts the actual times for each block server, and

wherein the return time update unit updates the estimated return times stored in the estimated return time storage unit with the actual times counted by the return time counter for each frame block server.

8. The video server of claim 2, wherein the frame block output unit includes:

a frame block receipt unit for receiving the frame blocks addresses to the self's subscriber interface;

a block buffer for accumulating a certain number of frame blocks received by the frame block receipt unit;

an accumulated amount judgment unit for judging whether the block buffer stores more than a predetermined number of frame blocks; and

an output unit for outputting the certain number of the frame blocks accumulated in the block buffer when the accumulated amount judgment unit judges that the block buffer stores more than the predetermined number of frame blocks, one frame block being outputted at a time to the request-sender subscriber terminal.

9. The video server of claim 8, wherein the frame block output unit further includes a check unit for checking an overflow and an underflow occurring at the block buffer, and

wherein the readout request transmission unit includes a transmission control unit for controlling a readout-request transmission in such a way that the readout request are transmitted after the predetermined timing upon detection of the overflow by the check unit, and before the predetermined timing upon detection of the underflow by the check unit.

10. The video server of claim 8, wherein each subscriber interface further includes a detection unit for detecting an amount of remaining frame blocks in the block buffer, and

wherein the readout request transmission unit includes a transmission control unit for controlling a readout-request transmission in such a way that the readout requests are transmitted when the amount of remaining frame blocks falls below a predetermined threshold.

11. The video server of claim 8, wherein the output unit outputs the certain number of the frame blocks in the block buffer at predetermined intervals, one frame block being outputted to the request-sender subscriber terminal at a time, the predetermined interval varying depending on a length of a video played with digital image data for one frame block.

12. The video server of claim 2, wherein each subscriber interface is connected to a plurality of subscriber terminals, each subscriber terminal outputting a video request including a terminal identifier, and

wherein the management data obtainment unit further includes an identifier detection unit for detecting the terminal identifiers contained in the video requests sent from the subscriber terminals upon receipt thereof, and

wherein the readout request transmission unit further includes an identifier attachment unit for attaching the terminal identifiers detected by the identifier detection unit to each readout request generated by the readout request generation unit, and

wherein the readout control unit in each frame block server includes:

a readout request receipt unit for detecting the terminal identifiers when receiving the readout requests from the readout request transmission unit; and

a frame block transmission unit for attaching the terminal identifiers detected by the readout request receipt unit to each request frame block read out as per the readout requests before the transmission thereof to the request-sender subscriber interface, and

wherein the frame block output unit further includes a distribution output control unit for receiving the terminal-identifier-attached frame blocks and in response outputting the same to the request-sender subscriber terminal identified by the terminal identifier.

13. The video server of claim 12, wherein the readout request transmission unit includes:

a most recent transmission time storage unit for storing a transmission time when a readout request is transmitted most recently;

a transmission judgment unit for judging whether a readout request is being transmitted for another subscriber when the management data obtainment unit receives a video request from one subscriber;

a time control unit for controlling a readout-request transmission for one subscriber while the readout request for another subscriber is being transmitted in such a way that a first readout request for the video request from the former subscriber is transmitted after a certain interval from the most recent transmission time, and that a second and subsequent readout requests are transmitted at predetermined issuance intervals from the transmission of the first readout request, the certain interval being found by multiplying a mean frame-block transmission rate of the plurality of subscriber interfaces in transmitting the frame blocks to the request-sender subscriber terminals by the number of the connected subscriber terminals, and dividing an amount of data of one frame block by the resulting value, the predetermined issuance interval being found by dividing the frame-block data amount by the transmission rate of one frame block.

14. The video server of claim 12, wherein the readout request transmission unit includes:

a transmission schedule generation unit for making out a transmission schedule of each readout request for a video requests upon receipt thereof by the management data obtainment unit;

a clock unit for showing a current time;

a transmission time buffer for storing a next scheduled time, the next scheduled time being a scheduled time nearest to the current time;

a transmission control unit for controlling a readout-request transmission in such a way that a readout request scheduled for the next scheduled time is transmitted when the clock unit shows the next scheduled time;

a transmission scheduled time determination unit for determining the transmission schedule, when the management data obtainment unit receives a video request from another subscriber, by setting the transmission scheduled time for a first readout request after a predetermined interval from the next scheduled time, and by setting scheduled times for second and subsequent readout requests at predetermined issuance intervals from the scheduled time for the first readout request;

a schedule write unit for writing the transmission scheduled times determined by the transmission scheduled time determination unit into the transmission schedule, the certain interval being found by multiplying a mean frame-block transmission rate of the plurality of subscriber interfaces in transmitting the frame-blocks to the request-sender subscriber terminals by the number of the connected subscriber terminals, and dividing an amount of data of one frame block by the resulting value, the predetermined issuance interval being found by dividing the frame-block data amount by the transmission rate of one frame.

15. The video server of claim 2, wherein the management data are a sequential file where the block pointers are aligned in a same sequence as a frame-block transmission sequence, and

wherein the readout request transmission unit includes:

a playback mode judgment unit for receiving a playback mode signal from the subscriber terminal and discriminating a playback mode contained therein;

a first transmission unit for transmitting the readout requests generated with the block pointers in the sequence in the management data when a normal playback mode is discriminated; and

a second transmission unit for transmitting the readout requests generated with the block pointers in the sequence in the management data by skipping a number of block pointers when a fast playback mode is discriminated, the number of skipped bock pointers corresponding to a video-play speed.

16. The video server of claim 15, wherein each subscriber interface includes:

a block pointer retrieval unit for retrieving a predetermined number of block pointers from the management means in the sequence in the management data;

a pointer buffer for holding the predetermined number of block pointers retrieved by the block pointer retrieval unit; and

a retrieval direction unit for directing a retrieval of the predetermined number of block pointers when the number of block pointers remaining in the pointer buffer falls below a predetermined threshold.

17. The video server of claim 16, wherein the management means further includes:

a retrieval amount detection unit for detecting the number of block pointers retrieved by the block pointer retrieval unit; and

a charge unit for calculating charges for each request-sender subscriber based on the number of the retrieved block pointers.

18. The video server of claim 2, wherein the exchange means is an ATM cell switch for exchanging cells, and

wherein each image memory is a disk array comprising K disk drives for storing the frame blocks, and

wherein each block pointer includes an address of each frame block server storing each frame block, and an address of the frame block in the disk array, and

wherein the readout request is of a cell structure, and the readout request transmission unit writes the address of frame block server in a header area of the cell structure while writing the address of the frame block in the disk array in a data area of the cell structure to generate a readout request for each block pointer, and

wherein the readout control unit in the frame block server detects the address of the frame block in each readout request and reads out the requested frame block by accessing to the address of the disk array.

19. The video server of claim 18, wherein the disk array comprises K disk drives interconnected by a SCSI, and the address of the frame block is formatted for a readout command in a SCSI system.

20. The video server of claim 18, wherein the readout control unit in each frame block server includes:

K queues for holding the readout requests to read out the requested frame blocks from corresponding disk drives in an order of receipt, one queue being furnished for one disk drive;

a readout request receipt unit for receiving the readout requests addressed to the self's frame block server;

an address analysis unit for detecting the address of the request frame blocks contained in each readout request received the readout request receipt unit and in response specifying the disk drives to which each readout request is addressed using the detected address, and for having the queue furnished for the specified disk drive store the readout request;

a disk access unit for retrieving one readout request from the K queues, and in response accessing to a memory area in the specified disk drive at the address contained in the readout request to have the disk drive read out from the requested frame block;

a transmission stand-by buffer for holding the frame blocks read out from the K disk drives; and

a frame block transmission unit for retrieving the frame blocks from the transmission stand-by buffer to transmit to the request-sender subscriber interface.

21. The video server of claim 20, wherein the frame block transmission unit includes:

a readout request storage unit for storing a readout request for which a requested frame block has been read out and stored in the transmission stand-by buffer together with a correlation with the frame block;

a frame block retrieval unit for retrieving the frame blocks from the transmission stand-by buffer;

a request-sender detection unit for detecting a request-sender subscriber interface of the readout request for the frame block retrieved from the transmission stand-by buffer;

a frame block division unit for dividing the retrieved frame block from the transmission stand-by buffer into a set of sub-blocks of an equal size;

a writing unit for writing each sub-block into the data area of the cell structure, and writing the request-sender detected by the request-sender detection unit into the header area of the cell structure; and

a cell transmission unit for transmitting the cells written with the sub-block and the request sender subscriber interface to the request-sender subscriber interface.

22. The video server of claim 21, wherein the frame block transmission unit includes:

a monitor unit for monitoring an overflow occurring in the ATM cell switch; and

a disallow unit for disallowing the cell transmission unit to transmit the cells in case of an overflow, and for allowing the cell transmission unit to transmit the cells when the overflow is eliminated.

23. The video server of claim 21, wherein the readout control unit in each frame block server includes:

a delay timer for counting a time for each readout request upon receipt thereof, a time-out occurring when the delay timer counts up a predetermined value; and

a delayed data write unit for writing delay data indicating a delay into the cells of a frame block which has been read out by a time-out readout request, and

wherein the ATM cell switch includes:

a higher priority queue for storing the cells which have delay priority in an order of arrival;

a lower priority queue for storing the cells which do not have the delay priority in an order of arrival; and

an exchange control unit for controlling a cell exchange in such a way that the cells in the higher priority queue are transmitted first, and then the cells in the lower priority queue are transmitted.

24. The video server of claim 20, wherein the readout control unit in each same block server further includes:

a flat register, each bit therein corresponding to readout requests in the K queues respectively;

a disk monitor unit for monitoring whether one of the K disk drive which stores a frame block requested by a readout request is reading out any other frame block,

a requested frame block judgment unit for specifying the frame block requested by the received readout request when the disk monitor unit judges that the disk drive is reading out the another frame block;

a readout request detection unit for detecting all readout requests requesting the from block specified by the requested frame block judgment unit from the K queues and setting the bits for each request;

a bit judgment unit for judging whether the bit in the flag register is set for a first-accumulated readout request in the queue when the disk monitor unit judges a completion of the readout of the another frame block by the queue;

a readout request detection unit for retrieving all the bit-set readout requests in the queue when the bit judgment unit judges the bit is set for the first-accumulated readout request; and

a request-sender list generation unit for detecting the request-sender subscriber interface for each readout request retrieved by the readout signal request detection unit to generate a list of the request-senders, and for attaching the list to the corresponding frame blocks in the transmission stand-by buffer, and

wherein the frame block transmission unit transmits a frame block with the request-sender list, and

wherein the video server further comprises a copy server for receiving the frame block with the request-sender list, and in response making copies of the frame block in a matching number with the request-sender subscriber interfaces in the request-sender list, and for transmitting the copies to the request-sender subscriber interfaces in the request-sender list respectively.

25. The video server of claim 20, wherein the readout control unit in each frame block server further includes:

a table hold unit for holding a table comprising entries, each entry showing a correlation between the frame blocks and the request-sender subscriber interfaces of the readout requests for the frame blocks respectively;

a fill-out unit for receiving the readout requests and in response writing their respective request-sender subscriber interfaces in the entries;

a request sender detection unit for detecting any other request-sender subscriber interface for one frame block while referring to the table when the frame block transmission unit transmits the frame block; and

a copy unit for making copies of the frame block, when the request sender detection unit detects other request sender subscriber interface, in a matching number of the other request-sender subscriber interfaces, and

wherein the frame block transmission unit transmits the frame block copies to the other request-sender subscribers detected by the request sender detection unit respectively.

26. The video server of claim 20, wherein the readout control unit in each frame block server further includes:

a threshold judgment unit for judging whether an amount of accumulation of each queue has reached a first threshold each time the readout request receipt unit receives a readout request;

an excess amount counter for storing an amount exceeding the threshold for each queue by counting one for the excess amount when the threshold judgment unit judges that the amount of accumulation exceeds the first threshold;

a queue data storage unit for storing data related to the queues that had accumulated the readout requests for each frame block stored in the transmission stand-by buffer;

an excess amount judgment unit for specifying the queues corresponding to the frame blocks in the transmission stand-by buffer while referring to the queue data storage unit, and for judging whether the excess amount for the specified queue has counted more than once;

a higher priority queue judgment unit for detecting a queue whose excess amount has been counted once or more when the excess amount of the specified queues has not counted;

a transmission control unit for controlling a frame-block transmission in such a way that the frame blocks read out by the readout requests stored in the queue detected by the higher priority queue judgment are transmitted;

a dummy request storage unit for storing dummy requests when the excess amount judgment unit judges that no excess amount has been counted up, the dummy request being of a same size as the readout request, and

wherein the disk drive discards a dummy request without reading out any frame block when the disk drive retrieves the dummy. request.

27. The video server of claim **26**, wherein the readout control unit in the frame block server further includes:

a second threshold judgment unit for judging whether an amount of accumulation of a queue whose excess amount is below a second threshold when the excess amount judgment unit judges that the excess amount of the queue has not been counted, the second threshold being smaller than the first threshold, and

wherein the higher priority queue detection unit retrieves the data related to the queue whose amount of accumulation is judged to be below the second threshold by the second threshold judgment unit.

28. The video server of claim **26**, wherein the readout control unit in the frame block server further includes:

an estimated process time storage unit for storing a time required to process all readout requests in each queue as an estimated process time;

an estimation process time computation unit for computing an estimated process time for each queue each time a readout request is stored in the queue, and for having the estimated process time storage unit store the estimated process time, the estimated process time being computed by adding the sum of a time required to read out the frame block as per readout request and a time required to transmit the frame block, and multiplying the sum by the number of the readout requests in the queue;

a threshold judgment unit for judging whether the estimated process time is below a predetermined threshold for the queue whose excess amount is judged as not having been counted by the excess amount judgment unit, and

wherein the higher priority queue judgment unit specifies the queue whose amount of accumulation is judged to be below the threshold by the threshold judgment unit.

29. The video server of claim **28**, wherein the readout control unit in each frame block server further includes an estimated process time transmission unit for transmitting the estimated process time computed by the estimated process time computation unit to the request-sender subscriber interface each time a readout request is stored in the queue, and

wherein the readout request transmission unit includes a transmission control unit for receiving the estimated process time transmitted by the estimated process time transmission unit for controlling a readout-request transmission in such a way that the readout requests are transmitted before the predetermined timing based on the received estimated process time.

30. The video server of claim **20**, wherein each frame block server includes:

a discard timer for counting a time for the readout request each time a readout request is received, a time-out occurring when the discard timer counts up a predetermined value; and

a first discard unit for discarding a frame block read out as per a time-out readout request.

31. The video server of claim **30**, wherein each subscriber interface includes:

a return time timer for counting a time between a transmission of the readout request and a receipt of the requested frame block, a time-out occurring when the return time counts up a predetermined value;

a second discard unit for discarding a frame block received after time-out occurs in the return time timer for the readout request, and

wherein the time-out is found by a following equation:

$$Tm1=Td1-Ta1-Tb1$$

where

Tm1 is the time-out for the discard timer;

Td1 is the time-out for the return time timer;

Ta1 is a minimum delay time between the transmission of the readout request by the readout request transmission unit and the transmission of the requested frame block by the frame block transmission unit; and

Tb1 is a minimum delay time between the frame block transmission by the frame block transmission unit and the receipt of the frame block by the frame block output unit.

32. The video server of claim **20**, wherein the frame block server includes:

a first discarded timer for counting a time for each frame block stored in the transmission stand-by buffer, a time-out occurs when the first discard timer counts up a redetermined value; and

a frame block discard unit for discarding a time-out frame block.

33. The video server of claim **32**, wherein each subscriber interface includes:

a return time timer for counting a time between a transmission of the readout request and a receipt of the requested frame block, a time-out occurring when the return time counts up a predetermined value;

a second discard unit for discarding a frame block received after time-out occurs in the return time timer for the readout request, and

wherein the time-out is found by a following equation

$$Tm1=Td1-Ta1-Tb1$$

where

Tm1 is the time-out for the discard timer;

Td1 is the time-out for the return time timer;

Ta1 is a minimum delay time between the transmission of the readout request by the readout request transmission unit and the transmission of the requested frame block by the frame block transmission unit; and

Tb1 is a minimum delay time between the frame block transmission by the frame block transmission unit and the receipt of the frame block by the frame block output unit.

34. The video server of claim **2**, wherein the readout control unit includes:

a timer for counting a time for each readout request each time a readout request is received, a time-out occurring when the timer counts up a predetermined value; and

a transmission control unit for controlling a frame-block transmission in such way that the frame blocks are transmitted when the time-out occurs for the corresponding readout request.

35. The video server of claim 2, wherein the ATM cell switch includes:

an exchange unit for exchange the frame blocks and the readout requests;

a passing timing detection unit for detecting timing at which the frame blocks and the readout requests pass by;

a passing time timer for counting a time between a passing of the readout request and a passing of the requested frame block; and

a first discard unit for discarding a frame block for which the passing time timer has counted a value larger than a redetermined value.

36. The video server of claim 35, wherein the passing timing detection unit in the ATM cell switch includes:

a return time timer for counting a time between a transmission of the readout request and a receipt of the requested frame block, a time-out occurring when the return time timer counts up a predetermined value; and

a second discard unit for discharging a frame block when the frame block is received after the time-out occurs in the return time timer, and

wherein the predetermined time for the first discard unit is found by a following equation:

$$Tm2=Td1-Tf1-Tg1$$

where

Tm2 is the predetermined time for the first discard unit;

Td1 is the time-out for the return time timer;

Tf1 is a minimum delay time between the transmission of the readout request from a subscriber interface and a detection of the readout request by the passing timing detection unit,

Tg1 is a minimum delay time between a transmission of the frame block by the passing timing detection unit and a receipt of the frame block by the subscriber interface.

37. The video server of claim 1, wherein the readout requests and the frame blocks are identified by identification numbers, and

wherein the exchange means includes:

an exchange unit for exchanging the frame blocks and the readout requests;

a passing timing detection unit for detecting timing at which the frame block and the readout request pass;

a frame block identifier detection unit for detecting an identification number M of a frame block when the passing timing detection unit detects a passing of the frame block;

a readout request passing monitor unit for detecting an identification number M+N of a readout request when the passing timing detection unit detects a passing of the readout request;

a passing time timer for counting a time between a passing of the readout register identified by the identification number M+N and a passing of the frame block identified by the identification number M;

an estimated passing time computation unit for computing a delay time Tm3+N·Ts between a passing of a readout request identified by an identification number M and the frame block identified by the identification number M, where Tm3 is a counting value of the passing time timer, N is a balance between the identification number of the frame block and the readout request, and Ts is a transmission interval between the readout requests; and

a first discard unit for discarding the frame block whose passing is detected by the frame block identifier detection unit when the estimated passing time computed by the estimated passing time consumption unit is longer than a predetermined time.

38. The video server of claim 37, wherein the passing timing detection unit in the ATM cell switch includes:

a return time timer for counting a time between a transmission of the readout request and a receipt of the requested frame block, a time-out occurring when the return time timers counts up a predetermined value; and

a second discard unit for discarding a frame block when the frame block is received after the time-out occurs in the return time timer, and

wherein the predetermined time for the first discard unit is found by a following equation:

$$Tm2=Td1-Tf1-Tg1$$

where

Tm2 is the predetermined time for the first discard unit;

Td1 is the time-out for the return time timer;

Tf1 is a minimum delay time between the transmission of the readout request from a subscriber interface and a detection of the readout request by the passing timing detection unit,

Tg1 is a minimum delay time between a transmission of the frame block by the passing timing detection unit and a receipt of the frame block by the subscriber interface.

39. The video server of claim 1, wherein the management means includes:

a transmission rate storage unit for storing a transmission rate for each piece of digital video data;

a transmission rate retrieval unit for retrieving the transmission rate for the requested digital video data from the transmission rate storage unit when the management data obtainment unit receives the video request;

a traffic amount detection unit for detecting a traffic amount in the exchange means when the transmission rate retrieval unit retrieves the transmission rate; and

a rejection unit for judging whether the video request received by the management data obtainment unit should be accepted or rejected based on the transmission rate retrieved by the transmission rate retrieval unit and the traffic amount detected by the traffic amount detection unit, and

wherein each subscriber interface includes a notice unit for outputting a rejection notice to the request-sender subscriber terminal when the rejection unit judges to reject the video request.

40. The video server of claim 1, wherein the management means further includes a charge unit for charging each subscriber depending on a number of the block pointers corresponding to a requested piece of digital video data.

41. The video server of claim 1, wherein the exchange means is an ATM cell switch for exchange cells, and

wherein the frame block server includes:

a transmission stand-by buffer for holding the frame blocks in a order of transmission;

a readout request storage unit for storing a readout request of which a requested frame block has been read out and stored in the transmission stand-by buffer together with correlation with the frame block;

a frame block retrieval unit for retrieving the frame blocks from the transmission stand-by buffer;

a request-sender detection unit for detecting a request-sender subscriber interface of the readout request for the frame block retrieved from the transmission stand-by buffer;

a frame block division unit for dividing the retrieved frame block from the transmission stand-by buffer into a set of sub-blocks of an equal size;

a writing unit for writing each sub-block into the data area of the cell structure, and writing the request sender detected by the request sender detection unit into the header area of the cell structure; and

a cell transmission unit for transmitting the cells written with the sub-block and the request-sender subscriber interface to the request-sender subscriber interface.

42. The video server of claim 41, wherein the frame block transmission unit includes:

a monitor unit for monitoring an overflow occurring in the ATM cell switch; and

a disallow unit for disallowing the cell transmission unit to transmit the cells in case of an overflow, and for allowing the cell transmission unit to transmit the cells when the overflow is eliminated.

43. The video server of claim 41, wherein each image memory includes a disk array comprising a plurality of disk drives, and

wherein the readout control unit further includes a plurality of queues, each queue being furnished for each disk drive respectively, and holding the readout requests to read out the frame blocks from their corresponding disk drives.

44. The video server of claim 43, wherein the readout request includes an address of each frame block server that stores each frame block, and an address of the frame block in the frame block server in a corresponding disk array, and

wherein the readout request is of a cell structure, and each subscriber interface writes the address of the frame block server in a header area of the cell structure and the address of the frame block server in a data area of the cell structure.

45. The video server of claim 8, wherein the number of subscribers to whom the video server can supply the digital video data must satisfy a following equation:

$$NSB<EX/(p\times rt)$$

where

NSB is the number of the subscribers who can access to the video server simultaneously,

EX is an exchange ability of the switch means,

rt is a transmission rate of a cable line interconnecting each subscriber interface and each subscriber terminal,

p is a use frequency per subscriber (times/second).

46. The video server of claim 45, wherein the number of the frame block servers is found by

$$NDB>EX/rr$$

where

NDB is the number of the frame block servers,

rr is a maximum retrieval rate of the frame block server.

47. The video server of claim 46, wherein the number of the subscribers who can access to the video server at a time is found by

$$NACC=NDB\times(rr/rt)$$

wherein

NACC is the number of the subscribers.

48. The video server of claim 47, wherein a memory capacity of each frame block server can be found by

$$Mem=(DB\times NB)$$

where

Mem is the memory capacity of the frame block server,

DB is a data size of one frame block,

NB is the maximum number of the frame blocks stored in one frame block server, and

wherein the total memory capacity must satisfy an equation

$$Mem>Sm\times T\times rt/NDB$$

where

Sm is the number of source videos,

T is a length of a piece of digital video data.

49. The video server of claim 48, wherein a memory capacity of the block buffer in each subscriber interface is found by

$$B>tr(rr-rt)$$

where

B is the memory capacity of the block buffer,

tr is a time required to transmit the frame block from the frame block server to the subscriber interface.

50. A video server which transmits digital video data comprising frame blocks having a predetermined sequence and stored therein to subscriber terminals as per video requests and which can rewrite the digital video data comprising:

a plurality of frame block servers, each including an image memory, a readout control unit for the image memory, and a writing control unit for the image memory, each image memory storing a plurality of said frame blocks nonconsecutive with respect to said predetermined display sequence, the read control unit receiving readout requests and in response reading out requested frame blocks from the adequate image memory, the write control unit receiving a write request and in response writing the frame blocks into the image memory;

management means for storing management data specifying which frame block server stores which frame block in the image memory and which frame block server has a writable area in the image memory, and for updating the management data each time a frame block is written in the image memory;

a plurality of subscriber interfaces for receiving the video requests from the subscriber terminals, and in response sending readout requests to frame block servers to readout frame blocks forming requested digital image data in said predetermined sequence while referring to the management data, and for transmitting the frame blocks transmitted from the frame block servers to the subscriber terminals at such timing that ensures continuous video-play;

a write interface for obtaining a digital video to divide the digital video into a set of sections, and for transmitting the divided sections to the frame block servers having the writable areas together with the write request, each section being of a same size as the frame block; and

exchange means for interconnecting each block server, each subscriber interface, and each write interface, and for transferring the frame blocks read out from the frame block servers and transmitted from the write interface to the request-sender subscriber interfaces and the frame block servers having the writable areas respectively.

51. The video server of claim **50**, wherein the management data comprise a plurality of block pointers, each identifying a location of each frame block respectively, and including an address of each frame block server that stores each frame block respectively, and

wherein each subscriber interface includes:

a management data obtainment unit for receiving the video request from the subscriber terminal, and in response retrieving block pointers for the requested piece of digital video data from the management means;

a readout request generation unit for generating a readout request for each retrieved block pointer addressing to the frame block server specified by the address included therein;

a readout request transmission unit for transmitting the readout requests to the specified frame block servers, one readout request being transmitted at a time; and

a frame block output unit for receiving the frame blocks read out as per the readout requests, and in response outputting the frame blocks to the request-sender subscriber terminal at the predetermined timing.

52. The video server of claim **51**, wherein the image memory in each frame block server has a memory area which is divided into a set of area, each area being sufficiently large to record one frame block, and

the management means includes:

a write pointer storage unit for storing write pointers, each write pointer being data showing a correspondence between the writable area in the image memory and its location;

a write control data generation unit for retrieving the write pointers for each frame block server from the write pointer storage unit when the write interface receives the write request, and for aligning the retrieved write pointers in sequence to generate write control data for a piece of digital video data to be recorded;

a management data conversion unit for converting the write control data generated by the write control data generation unit into the management data, and

wherein the write interface includes:

a management data obtainment unit for receiving the write request, and in response retrieving the write pointers for the piece of digital video data to be recorded from the management means; and

a write request generation unit for generating a write request for each retrieved write pointer addressing to the frame block server specified by the write pointer;

a division unit for generating a plurality of frame blocks by dividing the digital video data;

a write request transmission unit for transmitting the write requests first and then the requested frame blocks to the specified frame block servers, one of one write request and requested frame block being transmitted at a time, and wherein each specified frame block server writes the frame block on the writable area in the image memory specified by the write request when the write request and the frame block are received.

53. The video server of claim **52**, wherein the exchange means is an ATM cell switch for exchanging cells, and

wherein each image memory is a disk array comprising K disk drives for storing the frame blocks, and

wherein each block pointer includes an address of each frame block server storing each frame block, and an address of the frame block in the disk array, and

wherein each write pointer includes an address of a frame block server storing the corresponding frame block, and an address of the writable area in the disk array, and

wherein the readout request is of a cell structure, and the readout request transmission unit writes the address of the frame block server in a header area of the cell structure while writing the address of the frame block in the disk array in a data area of the cell structure to generate a readout request for each block pointer, and the write request transmission unit writes the address of the frame block server in the header area while writing the address of the writable area in the data area, and

wherein the readout control unit in the frame block server detects the address of the frame block in each readout request and reads out the requested frame block by accessing to the address of the disk array, and

wherein the write control unit in the frame block server detects the address of the frame block in each write request and writes the frame block in the writable area.

54. The video server of claim **53**, wherein the disk array comprises K disk drives interconnected by a SCSI, and the address of the frame block is formatted for a readout command in a SCSI system, and

wherein the address of the writable area is formatted for a write command in the SCSI system.

55. The video server of claim **53**, wherein the readout control unit in each frame block server includes:

K queues for holding the readout requests to read out the requested frame blocks from corresponding disk drives in an order of receipt, one queue being furnished for one disk drive;

a readout request receipt unit for receiving the readout requests addressed to the self's frame block server;

an address analysis unit for detecting the address of the requested frame block contained in each readout request received by the readout request receipt unit and in response specifying the disk drives to which each readout request is addressed using the detected address, and for having the queue furnished for the specified disk drive store the readout request;

a disk access unit for retrieving one readout request from the K queues, and in response accessing to a memory area in the specified disk drive at the address contained in the readout request to have the disk drive read out the requested frame block;

a transmission stand-by buffer for holding the frame blocks read out from the K disk drives; and

a frame block transmission unit for retrieving the frame blocks from the transmission stand-by buffer to transmit to the request-sender subscriber interface.

56. The video server of claim 55, wherein the write control unit includes:

a write request receipt unit for receiving the write requests addressed to the self's frame block server;

a frame block receipt unit for receiving the frame blocks addressed to the self's frame block server;

K queues for holding the write requests received by the write request receipt unit in an order of receipt, each queue being furnished for each disk drive respectively;

a frame block buffer for holding the frame blocks received by the frame block receipt unit;

an address analysis unit for detecting the address of the frame block in each write request received by the write request receipt unit, and for specifying the disk drive to which each write request is addressed using the detected address, and for having the queue furnished for the specified disk drive store the write request; and

a readout request judgment unit for judging whether there is any readout request in the queue furnished for the disk drive specified by the address analysis unit, and

wherein each disk drive forming the disk array includes a write control unit for writing the frame block as per the write request in the frame block buffer on the writable area specified by the address in the write request by retrieving the write request from the queue when there is no readout request in the queue.

57. The video server of claim 56, wherein the frame block transmission unit includes:

a readout request storage unit for storing a readout request for which a requested frame block has been read out and stored in the transmission stand-by buffer together with a correlation with the frame block;

a frame block retrieval unit for retrieving the frame blocks from the transmission stand-by buffer;

a request-sender detection unit for detecting a request-sender subscriber interfaces of the readout request for the frame block retrieved from the transmission stand-by buffer;

a frame block division unit for dividing the retrieved frame block from the transmission stand-by buffer into a set of sub-blocks of an equal size;

a writing unit for writing each sub-block into the data area of the cell structure, and writing the request-sender detected by the request-sender detection unit into the header area of the cell structure; and

a cell transmission unit for transmitting the cells written with the sub-block and the request-sender subscriber interface to the request-sender subscriber interface.

58. The video server of claim 57, wherein the frame block transmission unit includes:

a monitor unit for monitoring an overflow occurring in the ATM cell switch; and

a disallow unit for disallowing the cell transmission unit to transmit the cells in case of an overflow, and for allowing the cell transmission unit to transmit the cells when the overflow is eliminated.

59. The video server of claim 57, wherein the readout control unit in each frame block server includes:

a delay timer for counting a time for each readout request upon receipt thereof, a time-out occurring when the delay timer counts up a redetermined value; and

a delayed data write unit for writing delay data indicating a delay into the cells of a frame block which has been read out by a time-out readout request, and

wherein the ATM cell switch includes:

a higher priority queue for storing the cells which have delay priority in an order of arrival;

a lower priority queue for storing the cells which do not have the delay priority in an order of arrival; and

an exchange control unit for controlling a cell exchange in such a way that the cells in the higher priority queue are transmitted first, and then the cells in the lower priority queue are transmitted.

60. A video server which transmits digital video data comprising frame blocks having a predetermined sequence and stored therein to subscriber terminals as per video requests comprising:

a plurality of frame block servers, each including an image memory and a readout control unit for the image memory, each image memory storing a plurality of said frame blocks nonconsecutive with respect to said predetermined display sequence, the readout control unit receiving readout requests and in response reading out requested frame blocks from the image memory;

management means for storing management data specifying which frame block server stores which frame block in the image memory;

a plurality of subscriber interfaces for receiving the video requests from the subscriber terminals, and in response sending readout requests to the frame block servers to readout the frame blocks forming requested digital image data in said predetermined sequence while referring to the management data, and for transmitting the frame blocks transmitted from the frame block servers to the subscriber terminals at such timing that ensures continuous play, each subscriber interface being connected to a plurality of terminals; and

exchange means for interconnecting each block server and each subscriber interface to transfer the frame blocks read out from the frame block servers as per the readout requests to the request-sender subscriber interfaces.

61. The video server of claim 60, wherein the management data comprise a plurality of block pointers, each identifying a location of each frame block respectively, and including an address of each frame block server that stores each frame block respectively, and

wherein each subscriber interface includes:

a management data obtainment unit for receiving the video request from the subscriber terminal, and in response retrieving block pointers for the requested piece of digital video data from the management means;

a readout request generation unit for generating a readout request for each retrieved block pointer addressing to the frame block server specified by the address included therein;

a readout request transmission unit for transmitting the readout requests to the specified frame block servers, one readout request being transmitted at a time; and

a frame block output unit for receiving the frame blocks read out as per the readout requests, and in response outputting the frame blocks to the request-sender subscriber terminal at predetermined timing.

62. The video server of claim 61, wherein each subscriber interface is connected to a plurality of subscriber terminals, each subscriber terminal outputting a video request including a terminal identifier, and

wherein the management data obtainment unit further includes an identifier detection unit for detecting the terminal identifiers contained in the video requests sent from the subscriber terminals upon receipt thereof, and

wherein the readout request transmission unit further includes an identifier attachment unit for attaching the terminal identifiers detected by the identifier detection unit to each readout request generated by the readout request generation unit, and

wherein the readout control unit in each frame block server includes:

a readout request receipt unit for detecting the terminal identifiers when receiving the readout requests from the readout request transmission unit; and

a frame block transmission unit for attaching the terminal identifiers detected by the readout request receipt unit to each request frame block read out as per the readout requests before the transmission thereof to the request-sender subscriber interface, and

wherein the frame block output unit further includes a distribution output control unit for receiving the terminal-identifier-attached frame blocks and in response outputting the same to the request-sender subscriber terminal identified by the terminal identifier.

63. The video server of claim **62**, wherein the frame block output unit includes:

a frame block receipt unit for receiving the frame blocks addressed to the self's subscriber interface and attached with the terminal identifier;

a block buffer for accumulating a certain number of frame blocks received by the frame block receipt unit;

an accumulated amount judgment unit for judging whether the block buffer stores more than a predetermined number of frame blocks; and

an output unit for outputting the certain number of the frame blocks accumulated in the block buffer when the accumulated amount judgment unit judges that the block buffer stores more than the predetermined number of frame blocks, one frame block being outputted at a time to the request-sender subscriber terminal.

64. The video server of claim **63**, wherein the frame block output unit further includes a check unit for checking an overflow and an underflow occurring at the block buffer, and

wherein the readout request transmission unit includes a transmission control unit for controlling a readout-request transmission in such a way that the readout request are transmitted after the predetermined timing upon detection of the overflow by the check unit, and before the predetermined timing upon detection of the underflow by the check unit.

65. The video serve of claim **62**, wherein the exchange means is an ATM cell switch for exchanging cells, and

wherein each image memory is a disk array comprising K disk drives for storing the frame blocks, and

wherein each block pointer includes an address of each frame block server storing each frame block, and an address of the frame block in the disk array, and

wherein the readout request is of a cell structure, and the readout request transmission unit writes the address of the frame block server in a header area of the cell structure while writing the address of the frame block in the disk array in a data area of the cell structure to generate a readout request for each block pointer, and

wherein the readout control unit in the frame block server detects the address of the frame block in each readout request and reads out the requested frame block by accessing to the address of the disk array.

66. The video server of claim **65**, wherein the disk array comprises K disk drive interconnected by a SCSI, and the address of the frame block is formatted for a readout command in a SCSI system.

67. The video server of claim **65**, wherein the readout control unit in each frame block server includes:

K queues for holding the readout requests to read out the requested frame blocks from corresponding disk drives in an order of receipt, one queue being furnished for one disk drive;

an address analysis unit for detecting the address of the requested frame block contained in each readout request received by the readout request receipt unit and in response specifying the disk drives to which each readout request is addressed using the detected address, and for having the queue furnished for the specified disk drive store the readout request;

a disk access unit for retrieving one readout request from the K queue, and in response accessing to a memory area in the specified disk drive at the address contained in the readout request to have the disk drive read out the requested frame block;

a transmission stand-by buffer for holding the frame blocks read out from the K disk drives; and

a frame block transmission unit for retrieving the frame blocks from the transmission stand-by buffer, and for attaching the terminal identifier to the retrieved frame block to transmit to the request-sender subscriber interface.

68. The video server of claim **67**, wherein the frame block transmission unit includes:

a readout request storage unit for storing a readout request for which a requested frame block has been read out and stored in the transmission stand-by buffer together with a correlation with the frame block;

a frame block retrieval unit for retrieving the frame blocks from the transmission stand-by buffer;

a request-sender detection unit for detecting a request-sender subscriber interface of the readout request for the frame block retrieved from the transmission stand-by buffer;

an identifier attachment unit for attaching the terminal identifier in the retrieved readout request detected by the readout receipt unit to the requested frame block;

a frame block division unit for dividing the retrieved frame block attached with the terminal identifier from the transmission stand-by buffer into a set of sub-blocks of an equal size;

a writing unit for writing each sub-block into the data area of the cell structure, and writing the request-sender detected by the request-sender detection unit into the header area of the cell structure; and

a cell transmission unit for transmitting the cells written with the sub-blocks and the request-sender subscriber interface to the request-sender subscriber interface.

69. The video server of claim **68**, wherein the frame block transmission unit includes:

a monitor unit for monitoring an overflow occurring in the ATM cell switch; and

a disallow unit for disallowing the cell transmission unit to transmit the cells in case of an overflow, and for allowing the cell transmission unit to transmit the cells when the overflow is eliminated.

70. The video server of claim **68**, wherein the readout control unit in each frame block server includes:

a delay timer for counting a time for each readout request upon receipt thereof, a time-out occurring when the delay timer counts up a redetermined value; and

a delayed data write unit for writing delay data indicating a delay into the cells of a frame block which has been read out by a time-out readout request, and

wherein the ATM cell switch includes:

a higher priority queue for storing the cells which have delay priority in an order of arrival;

a lower priority queue for storing the cells which do not have the delay priority in an order of arrival; and

an exchange control unit for controlling a cell exchange in such a way that the cells in the higher priority queue are transmitted first, and then the cells in the lower priority queue are transmitted.

71. The video server of claim 61, wherein the readout request transmission unit includes:

a most recent transmission time storage unit for storing a transmission time when a readout request is transmitted most recently;

a transmission judgment unit for judging whether a readout request is being transmitted for another subscriber when the management data obtainment unit receives a video request from one subscriber;

a time control unit for controlling a readout-request transmission for one subscriber while the readout request for another subscriber is being transmitted in such a way that a first readout request for the video request from the former subscriber is transmitted after a certain interval from the most recent transmission time, and that a second and subsequent readout requests are transmitted at predetermined issuance intervals from the transmission of the first readout request, the certain interval being found by multiplying a mean frame-block transmission rate of the plurality of subscriber interfaces in transmitting the frame blocks to the request-sender subscriber terminals by the number of the connected subscriber terminals, and dividing an amount of data of one frame block by the resulting value, the predetermined issuance interval being found by dividing the frame-block data amount by the transmission rate of one frame block.

72. The video server of claim 61, wherein the readout request transmission unit includes:

a transmission schedule generation unit for making out a transmission schedule of each readout request for a video requests upon receipt thereof by the management data obtainment unit;

a clock unit for showing a current time;

a transmission time buffer for storing a next scheduled time, the next scheduled time being a scheduled time nearest to the current time;

a transmission control unit for controlling a readout-request transmission in such a way that a readout request scheduled for the next scheduled time is transmitted when the clock unit shows the next scheduled time;

a transmission scheduled time determination unit for determining the transmission schedule, when the management data obtainment unit receives a video request from another subscriber, by setting the transmission scheduled time for a first readout request after a predetermined interval from the next scheduled time, and by setting scheduled times for second and subsequent readout requests at predetermined issuance intervals from the scheduled time for the first readout request;

a schedule write unit for writing the transmission scheduled times determined by the transmission scheduled time determination unit into the transmission schedule, the certain interval being found by multiplying a mean frame-block transmission rate of the plurality of subscriber interfaces in transmitting the frame-blocks to the request-sender subscriber terminals by the number of the connected subscriber terminals, and dividing an amount of data of one frame block by the resulting value, the predetermined issuance interval being found by dividing the frame-block data amount by the transmission rate of one frame block.

73. A video server which transmits digital video data comprising frame blocks having a predetermined sequence and stored therein to subscriber terminals as per video requests comprising:

a plurality of frame block servers, each including an image memory and a readout control unit for the image memory, each image memory storing a plurality of said frame blocks nonconsecutive with respect to said predetermined display sequence, the readout control unit receiving readout requests and in response reading out requested frame blocks from the image memory;

management means for storing management data specifying which frame block server stores which frame block in the image memory;

a plurality of subscriber interfaces for receiving the video requests from the subscriber terminals, and in response sending readout requests to the frame block servers to readout the frame blocks forming requested digital image data in said predetermined sequence while referring to the management data, and for transmitting the frame blocks transmitted from the frame block servers to the subscriber terminals at such timing that ensures a continuous play; and

an exchange network including a plurality of exchange units interconnected to each other, each being selectively connected to a plurality of frame block servers and a plurality of subscriber interfaces for transferring the frame blocks addressed to the self's frame block server to the request-sender subscriber interfaces respectively.

74. The video server of claim 73, wherein the management data comprises a plurality of block pointers, each identifying a location of each frame block respectively, and including an address of each frame block server that stores each frame block respectively, and

wherein each subscriber interface includes:

a management data obtainment unit for receiving the video request from the subscriber terminal, and in response retrieving block pointers for the requested piece of digital video data from the management means;

a readout request generation unit for generating a readout request for each retrieved block pointer addressing to the frame block server specified by the address included therein;

a readout request transmission unit for transmitting the readout requests to the specified frame block servers, one readout request being transmitted at a time; and

a frame block output unit for receiving the frame blocks read out as per the readout requests, and in response outputting the frame blocks to the request-sender subscriber terminal at predetermined timing.

75. The video server of claim 74, wherein the exchange network is an ATM cell switch for transferring the cells, and

wherein each image memory is a disk array comprising K disk drives for storing the frame blocks, and

wherein each block pointer includes an address of each frame block server storing each frame block, and an address of the frame block in the disk array, and

wherein the readout request is of a cell structure, and the readout request transmission unit writes the address of the frame block server in a header area of the cell structure while writing the address of the frame block in the disk array in a data area of the cell structure to generate a readout request for each block pointer, and

wherein the readout control unit in the frame block server detects the address of the frame block in each readout request and reads out the requested frame block by accessing to the address of the disk array.

76. The video server of claim 75, wherein the disk array comprises K disk drives interconnected by a SCSI, and the address of the frame block is formatted for a readout command in a SCSI system.

77. The video server of claim 75, wherein the readout control unit in each frame block server includes:

K queues for holding the readout requests to read out the requested frame blocks from corresponding disk drives in an order of receipt, one queue being furnished for one disk drive;

a readout request receipt unit for receiving the readout requests addressed to the self's frame block server;

an address analysis unit for detecting the address of the requested frame block contained in each readout request received by the readout request receipt unit and in response specifying the disk drives to which each readout request is addressed using the detected address, and for having the queue furnished for the specified disk drive store the readout request;

a disk access unit for retrieving one readout request from the K queues, and in response accessing to a memory area in the specified disk drive at the address contained in the readout request to have the disk drive read out the requested frame block;

a transmission stand-by buffer for holding the frame blocks read out from the K disk drives; and

a frame block transmission unit for retrieving the frame blocks from the transmission stand-by buffer to transmit to the request-sender subscriber interface.

78. The video server of claim 77, wherein the frame block transmission unit includes:

a readout request storage unit for storing a readout request for which a requested frame block has been read out and stored in the transmission stand-by buffer together with a correlation with the frame block;

a frame block retrieval unit for retrieving the frame blocks from the transmission stand-by buffer;

a request-sender detection unit for detecting a request-sender subscriber interface of the readout request for the frame block retrieved from the transmission stand-by buffer;

a frame block division unit for dividing the retrieved frame block from the transmission stand-by user into a set of sub-blocks of an equal size;

a writing unit for writing each sub-block into the data area of the cell structure, and writing the request-sender detected by the request-sender detection unit into the header area of the cell structure; and

a cell transmission unit for transmitting the cells written with the sub-block and the request-sender subscriber interface to the request-sender subscriber interface.

79. The video server of claim 78, wherein the frame block transmission unit includes:

a monitor unit for monitoring an overflow occurring in the ATM cell switch; and

a disallow unit for disallowing the cell transmission unit to transmit the cells in case of an overflow, and for allowing the cell transmission unit to transmit the cells when the overflow is eliminated.

80. A method for storing and distributing a plurality of video data to a plurality of clients in response to video requests made by said clients comprising;

dividing each video into a plurality of discrete video segments and storing said video segments in a plurality of video segment file servers;

recording the location of each video segment and the intended sequence of each video segment in a control file, and storing each control file in a system manager;

providing a client interface which is connected to a plurality of client terminals for receiving client requests and communicating a readout request corresponding to said client request to a video file sequence manager;

communicating the control file of the video data corresponding to each readout request from said system manager to said video file sequence manager;

retrieving the video segments from the video segment file servers to the video file sequence manager according to said control file of the video data;

transmitting each video segment retrieved by said video file sequence manager to said client interface in a predetermined sequence profile specified by said control file and coordinated to achieve a continuous transmission of said video data; and

transmitting said continuous transmission of said video data from said client interface to said client.

81. The method for storing and transmitting video data as recited in claim 80 further including the step of monitoring the amount of video segments arriving at said video file sequence manager and temporarily storing said video segments in a buffer when an overflow occurs, and retrieving said video segments from said buffer into said video file sequence manager when said overflow has expired.

82. The method for storing and transmitting video data as recited in claim 81 further including the step of assigning priority to video segments having a shorter retrieval time to be transmitted by said video file sequence manager to said client interface whereby the continuous transmission of said video data is maintained.

83. The method for storing and transmitting video data as recited in claim 81 wherein the step of dividing the video data into video segments is performed to distribute an approximately equal number of video segments in each video segment file server.

84. A video storage and distribution system for accessing and transmitting video data to a plurality of subscribers according to submitted requests by said subscribers, said system designed to transmit a requested video data to multiple subscribers using a plurality of video storage units load balanced to operate at generally identical delivery loads, each said requested video data comprised of discrete video segments stored substantially equally among the plurality of video storage units, said system comprising:

a plurality of subscriber terminal means for transmitting subscriber requests for video data;

a subscriber interface connected to said plurality of subscriber terminal means adapted to receive said request for video data and generate a readout command for said requested video data;

a system control unit comprising sequence information and address information corresponding to said requested video data;

a plurality of video storage units comprising readout command receiving means for receiving one of said readout commands generated by said subscriber interface, video segment storage means for storing a plurality discrete video segment data corresponding to increments of said requested video data according to said address information, and video segment data retrieval means for retrieving said video segment data corresponding to said readout command; and

an exchange unit connected to each of said plurality of video storage units, said subscriber interface, and said system control unit, said exchange unit receiving said readout command from said subscriber interface and retrieving said sequence information and address information corresponding to said requested video data from said system control unit and submitting readout commands to the video storage unit corresponding with each video segment of said requested video data as determined by the address information and sequence information, said exchange unit thereafter receiving said video segment data retrieved by said video segment data retrieval means of said video storage unit, and said exchange unit thereafter transmitting said video segment data sequentially to said subscriber interface for continuous delivery to said subscriber terminal.

85. A method for transmitting a video image sequence of a predetermined duration concurrently to a plurality of clients in response to requests by said clients comprising:

dividing said video image sequence into a plurality of discrete video segments;

distributing said discrete video segments among a plurality of video segment storage units;

storing a storage address for each discrete video segment in a control unit, and storing a predetermined sequence data of said video segments in said control unit;

receiving a first request for said video image sequence from a first client;

transmitting said first request to a data exchange unit, which retrieves said sequence data and sends a request to the address of said video segment corresponding to said first video segment of said sequence data, and after receiving same transmitting said first video segment to said first user according to a predetermined schedule;

receiving a second request for said video image sequence from a second client;

transmitting said second request to said data exchange, which retrieves said sequence data and sends a request to the address of said video segment corresponding to said first video segment, and after receiving same transmitting said first video segment to said second user according to a predetermined schedule; and

locating and retrieving each successive video segment and transmitting each video segment to each requesting client according to said retrieved sequence and a predetermined schedule.

86. A system for storing, retrieving, and delivering a plurality of audio visual works such as feature length movies to a plurality of requesting clients, each audio-visual work being deliverable to a plurality of clients concurrently and delivery of said audio-visual work to each of said clients is independent of delivery of said audio-visual work to all other clients, said system comprising:

a plurality of video storage servers each comprising a computer interface and video data storage means for storing a plurality of video data blocks, each said video data block containing video data corresponding to a segment of one of said plurality of audio-visual works such that when each video data block corresponding to one of said audio-visual works is delivered continuously in a predetermined sequence said audio-visual work is reproduced, said video data blocks stored in said video storage servers such that no video storage server stores two sequential video data blocks of a given audio-visual work;

a sequence storage means for storing sequence information for each audio-visual work and for transmitting said sequence information, said sequence information comprising the predetermined sequence of the video data blocks and video storage server storing each video block;

a plurality of sequence control brokers connected to a plurality of clients, said sequence control brokers adapted to receive a video request for an audio-visual work from said client and generate a readout command for said video request, and further adapted to receive video data and transmit said video data to said client; and

a control unit connected to each of said plurality of sequence control brokers, said sequence storage means, and each of said video storage servers, said control unit adapted to receive said readout commands generated from said control brokers, retrieve the sequence information for the video request corresponding to said readout request, retrieve the video data sequentially from the plurality of video data servers for the audio-visual work according to said sequence information, and transmit the video data sequentially to the sequence control brokers such that an uninterrupted delivery of said audio-visual work to said client is achieved.

* * * * *

APPENDIX D

U.S. Patent No. 4,914,570 to Peacock

United States Patent [19]
Peacock

[11] Patent Number: 4,914,570
[45] Date of Patent: Apr. 3, 1990

[54] PROCESS DISTRIBUTION AND SHARING SYSTEM FOR MULTIPLE PROCESSOR COMPUTER SYSTEM

[75] Inventor: J. Kent Peacock, San Jose, Calif.

[73] Assignee: Counterpoint Computers, Inc., San Jose, Calif.

[21] Appl. No.: 223,729

[22] Filed: Jul. 21, 1988

Related U.S. Application Data

[63] Continuation of Ser. No. 907,568, Sep. 15, 1986, abandoned.

[51] Int. Cl.⁴ G06F 13/00; G06F 9/30
[52] U.S. Cl. 364/200; 364/229.2; 364/230.3; 364/280.9
[58] Field of Search ... 314/200 MS File, 900 MS File

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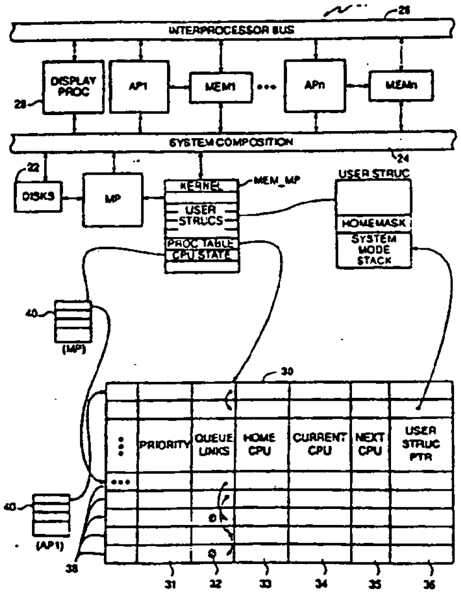
Primary Examiner—Eddie P. Chan
Attorney, Agent, or Firm—Flehr, Hohbach, Test, Albritton & Herbert

[57] ABSTRACT

A multiple processor (CPU) computer system, each CPU having a separate, local, random access memory means to which it has direct access. An interprocessor bus couples the CPUs to memories of all the CPUs, so that each CPU can access both its own local memory means and the local memories of the other CPUs. A run queue data structure holds a separate run queue for each of the CPUs. Whenever a new process is created, one of the CPUs is assigned as its home site and the new process is installed in the local memory for the home site. When a specified process needs to be transferred from its home site to another CPU, typically for performing a task which cannot be performed on the home site, the system executes a cross processor call, which performs the steps of: (a) placing the specified process on the run queue of the other CPU; (b) continuing the execution of the specified process on the other CPU, using the local memory for the specified process's home site as the resident memory for the process and using the interprocessor bus to couple the other CPU to the home site's local memory, until a predefined set of tasks has been completed; and then (c) placing the specified process on the run queue of the specified process's home site, so that execution of the process will resume on the process's home site.

13 Claims, 6 Drawing Sheets



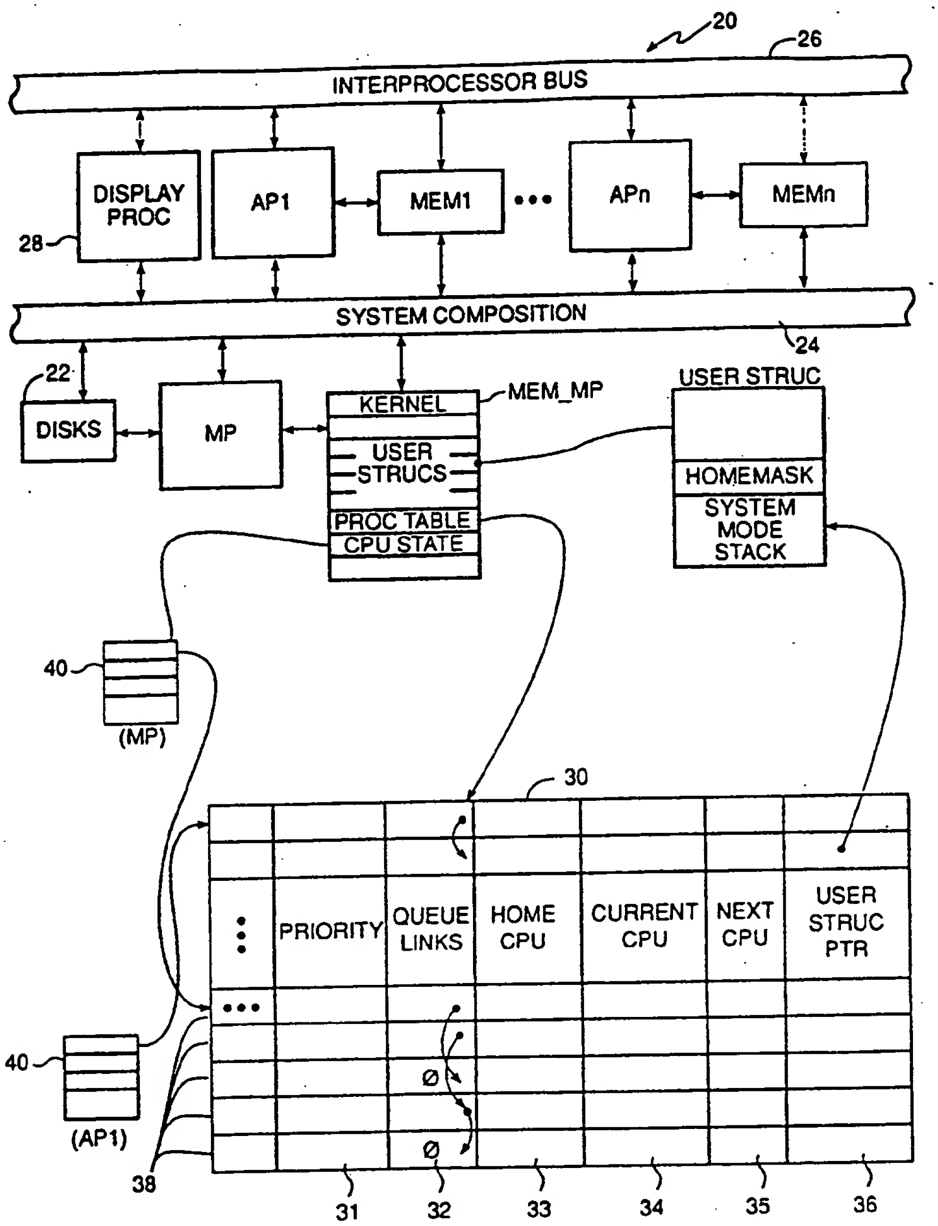

20
26
INTERPROCESSOR BUS
DISPLAY PROC
28
AP1
MEM1
APn
MEMn
SYSTEM COMPOSITION
24
22
DISKS
MP
KERNEL
USER STRUCS
PROC TABLE
CPU STATE
MEM_MP
USER STRUC
HOMEMASK
SYSTEM MODE STACK
40
(MP)
30
PRIORITY
QUEUE LINKS
HOME CPU
CURRENT CPU
NEXT CPU
USER STRUC PTR
Ø
Ø
40
(AP1)
38
31
32
33
34
35
36

FIGURE 1

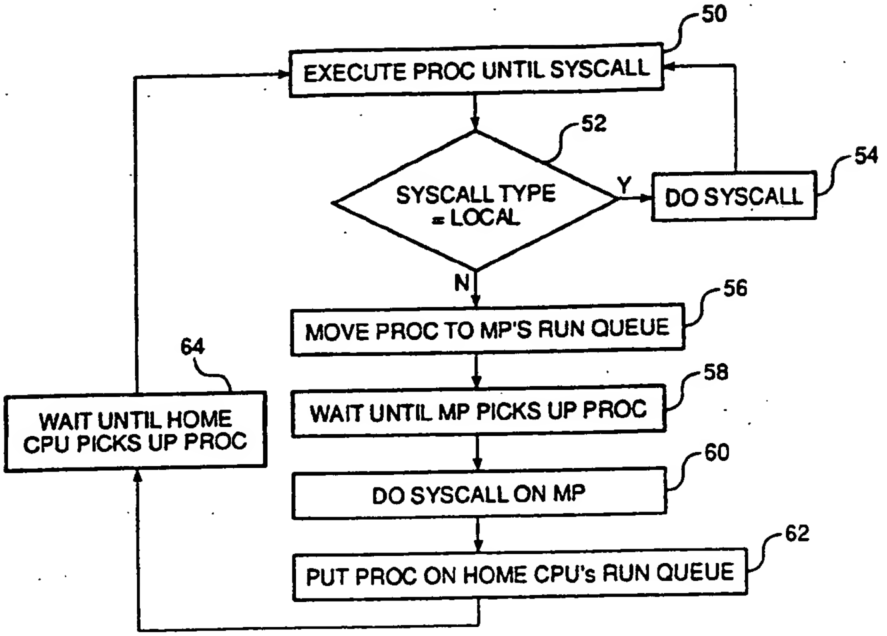

EXECUTE PROC UNTIL SYSCALL
50
SYSCALL TYPE = LOCAL
52
Y
DO SYSCALL
54
N
MOVE PROC TO MP'S RUN QUEUE
56
64
WAIT UNTIL MP PICKS UP PROC
58
WAIT UNTIL HOME CPU PICKS UP PROC
DO SYSCALL ON MP
60
PUT PROC ON HOME CPU's RUN QUEUE
62

FIGURE 2A

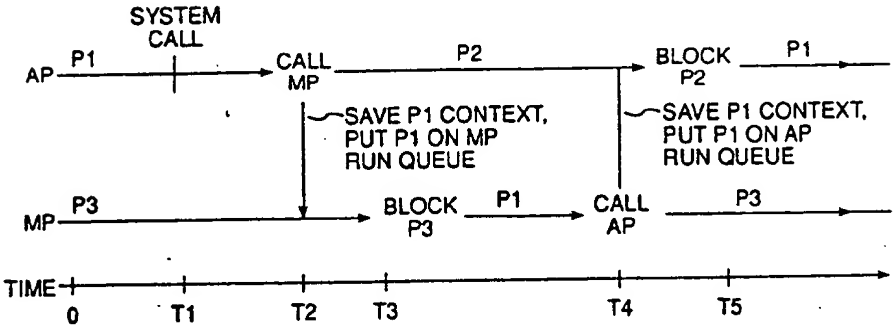

SYSTEM CALL
AP
P1
CALL MP
P2
BLOCK P2
P1
SAVE P1 CONTEXT, PUT P1 ON MP RUN QUEUE
SAVE P1 CONTEXT, PUT P1 ON AP RUN QUEUE
MP
P3
BLOCK P3
P1
CALL AP
P3
TIME
0
T1
T2
T3
T4
T5

FIGURE 2B

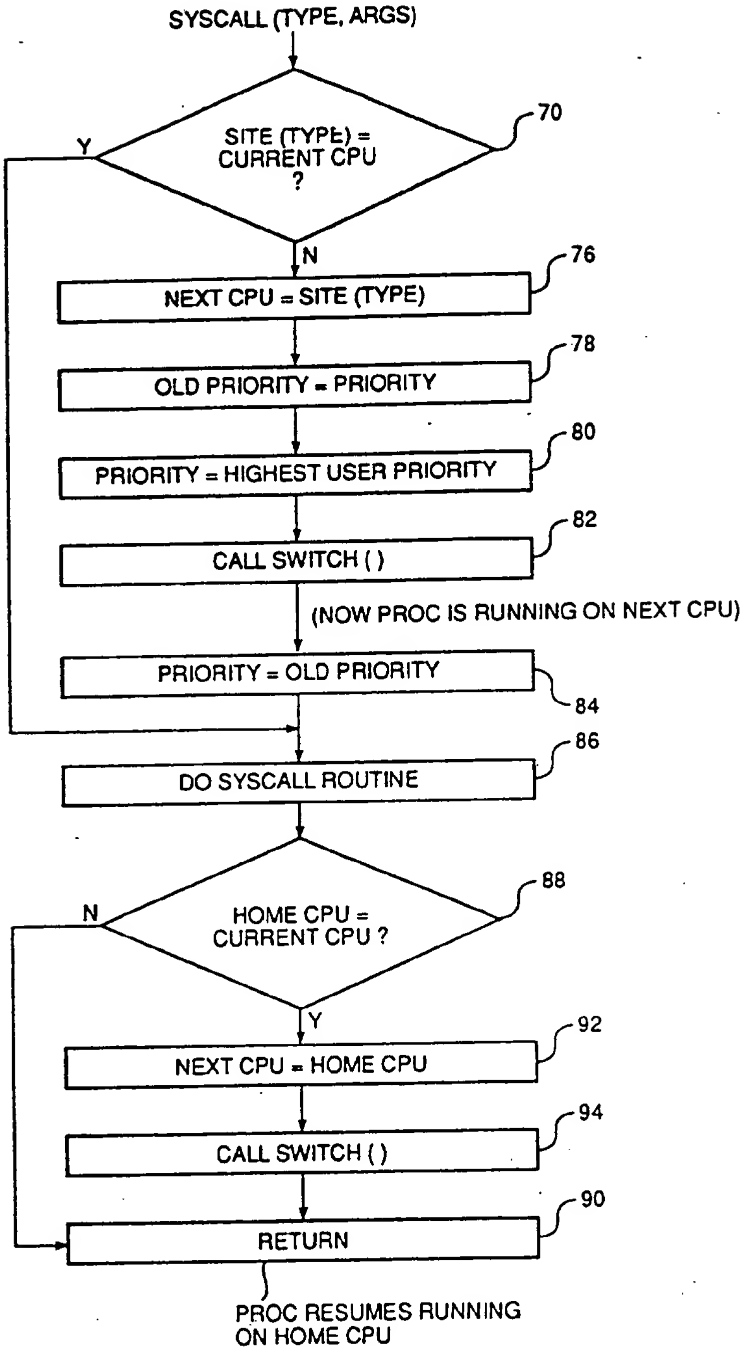

SYSCALL (TYPE, ARGS)
SITE (TYPE) = CURRENT CPU ?
70
Y
N
NEXT CPU = SITE (TYPE)
76
OLD PRIORITY = PRIORITY
78
PRIORITY = HIGHEST USER PRIORITY
80
CALL SWITCH ( )
82
(NOW PROC IS RUNNING ON NEXT CPU)
PRIORITY = OLD PRIORITY
84
DO SYSCALL ROUTINE
86
HOME CPU = CURRENT CPU ?
88
N
Y
NEXT CPU = HOME CPU
92
CALL SWITCH ( )
94
RETURN
90
PROC RESUMES RUNNING ON HOME CPU

FIGURE 4

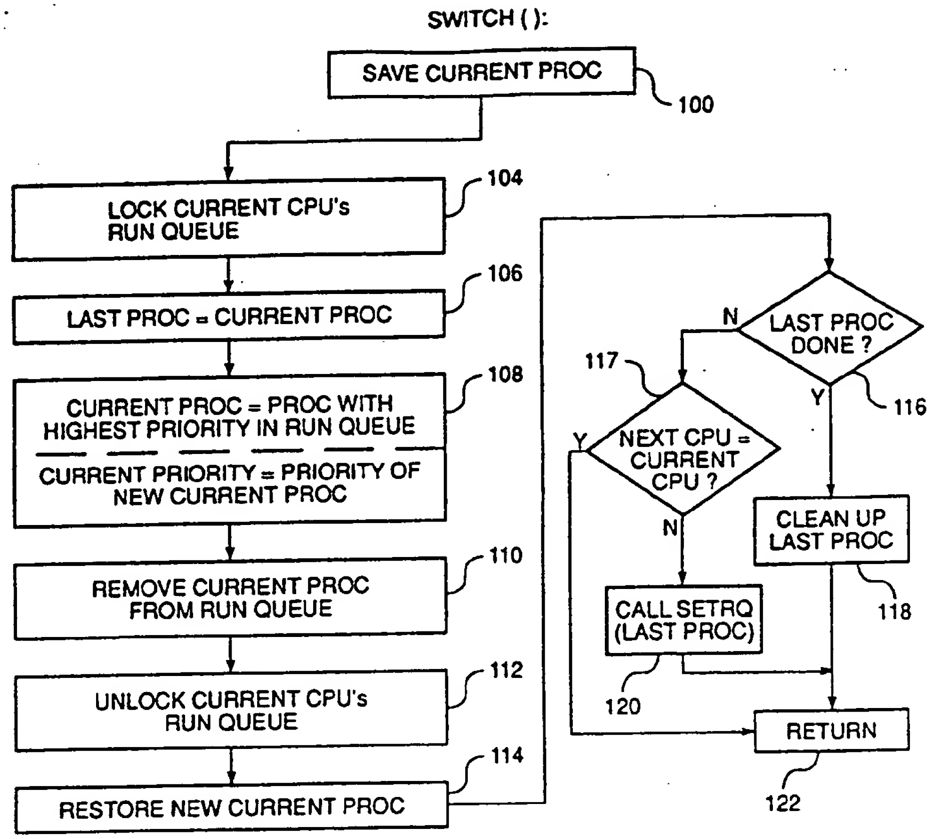

SWITCH ( ):
SAVE CURRENT PROC
100
LOCK CURRENT CPU's RUN QUEUE
104
LAST PROC = CURRENT PROC
106
CURRENT PROC = PROC WITH HIGHEST PRIORITY IN RUN QUEUE
CURRENT PRIORITY = PRIORITY OF NEW CURRENT PROC
108
REMOVE CURRENT PROC FROM RUN QUEUE
110
UNLOCK CURRENT CPU's RUN QUEUE
112
RESTORE NEW CURRENT PROC
114
LAST PROC DONE ?
N
Y
116
117
NEXT CPU = CURRENT CPU ?
Y
N
CLEAN UP LAST PROC
118
CALL SETRQ (LAST PROC)
120
RETURN
122

FIGURE 5

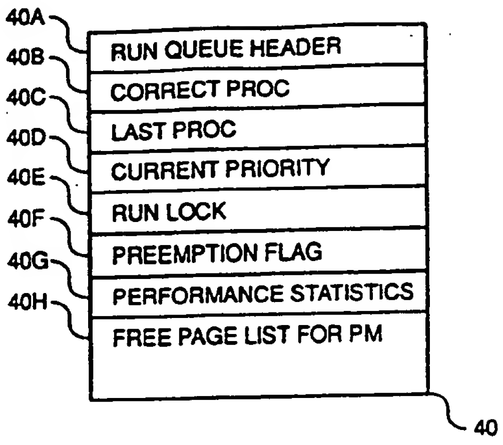
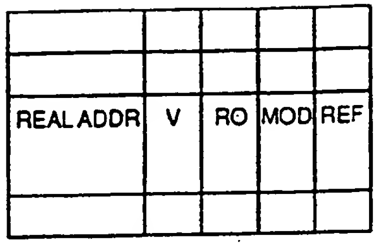


FIGURE 3



REAL ADDR	V	RO	MOD	REF

FIGURE 8

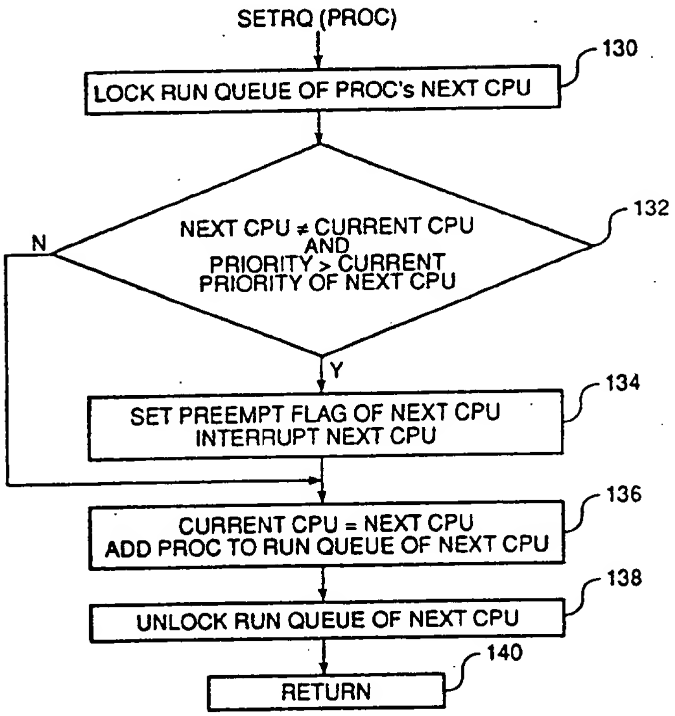

SETRQ (PROC)
LOCK RUN QUEUE OF PROC's NEXT CPU
130
NEXT CPU ≠ CURRENT CPU AND PRIORITY > CURRENT PRIORITY OF NEXT CPU
132
N
Y
SET PREEMPT FLAG OF NEXT CPU INTERRUPT NEXT CPU
134
CURRENT CPU = NEXT CPU ADD PROC TO RUN QUEUE OF NEXT CPU
136
UNLOCK RUN QUEUE OF NEXT CPU
138
RETURN
140

FIGURE 6

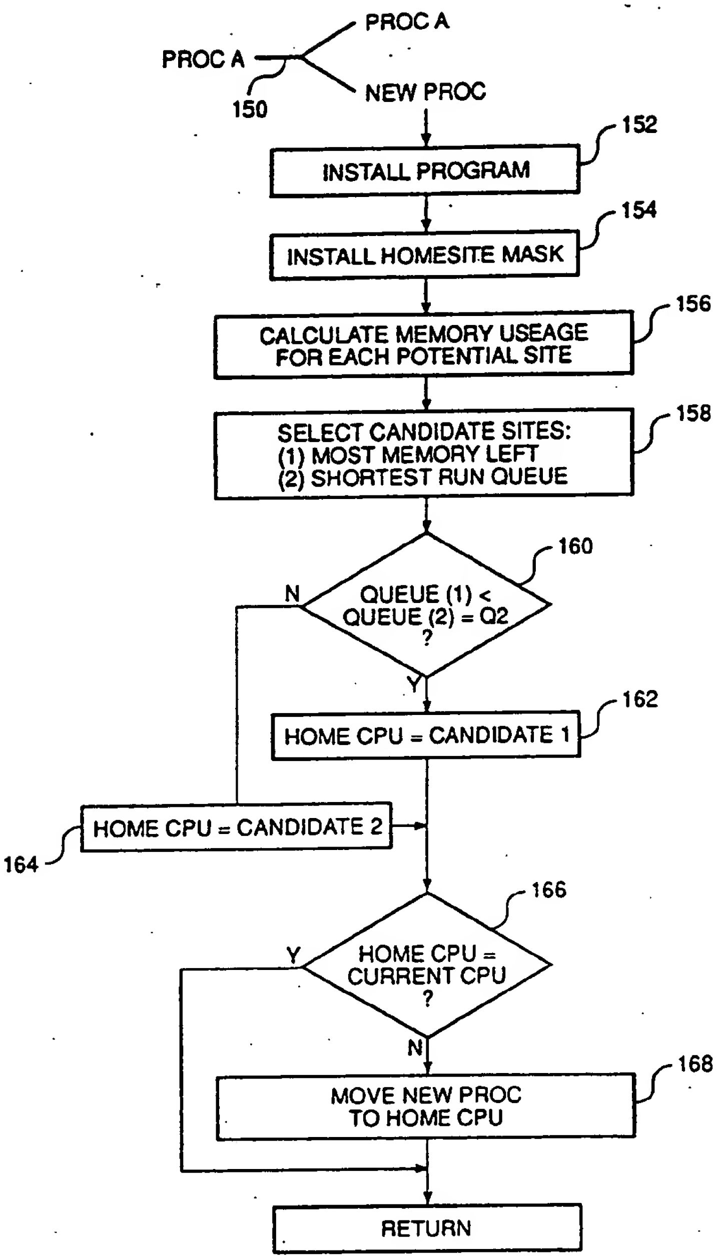

PROC A
PROC A
NEW PROC
150
INSTALL PROGRAM
152
INSTALL HOMESITE MASK
154
CALCULATE MEMORY USEAGE FOR EACH POTENTIAL SITE
156
SELECT CANDIDATE SITES:
(1) MOST MEMORY LEFT
(2) SHORTEST RUN QUEUE
158
QUEUE (1) < QUEUE (2) = Q2 ?
160
N
Y
HOME CPU = CANDIDATE 1
162
HOME CPU = CANDIDATE 2
164
HOME CPU = CURRENT CPU ?
166
Y
N
MOVE NEW PROC TO HOME CPU
168
RETURN

FIGURE 7

PROCESS DISTRIBUTION AND SHARING SYSTEM FOR MULTIPLE PROCESSOR COMPUTER SYSTEM

This is a continuation of application Ser. No. 907,568 filed Sept. 15, 1986, now abandoned.

The present invention relates generally to multiple processor computer systems, and particularly to apparatus and methods for moving a process from one site to another within a multiple processor computer system.

BACKGROUND OF THE INVENTION

The prior art includes a large number of different multiple processor computer systems, and a number of variations on the UNIX (a trademark of AT&T) operating system.

For the purposes of this introduction, multiple processor computer systems can be generally classified into two distinct types: (1) those that perform complex calculations by allocating portions of the calculation to different processors; and (2) those that are enhanced multitasking systems in which numerous processes are performed simultaneously, or virtually simultaneously, with each process being assigned to and performed on an assigned processor. The present invention concerns the second type of multiple processor system.

In order to avoid confusion between the terms "processor" (which is a piece of apparatus including a central processing unit) and "process" (which is a task being performed by a computer), the terms "site" and "CPU" shall be used herein synonymously with "processor". For instance, when a process is created, it is assigned to a particular site (i.e., processor) for execution.

As background, it should be understood that in any multitasking system, there is a "run queue" which is a list of all the processes which are waiting to run. In most systems the run queue is a linked list. When the system is done with one process (at least temporarily) and ready to start running another process, the system looks through the run queue and selects the process with the highest priority. This process is removed from the run queue and is run by the system until some event causes the system to stop the selected process and to start running another process.

In prior art multiple processor (also called multiple CPU) systems, there is generally a single large memory and a single run queue for all of the processors in the system. While the use of a single run queue is not inherently bad, the use of a single large memory tends to cause increasing memory bus contention as the number of CPUs in the system is increased.

Another problem associated with most multiple CPU computer systems, only one of the CPUs can perform certain tasks and functions, such as disk access. Therefore if a process needs to perform a particular function, but is running at a site which cannot perform that function, the computer system needs to provide a method for that process to perform the function at an appropriate site within the system.

Generally, the problems associated with such "cross processor calls" include (1) minimizing the amount of information which is moved or copied from one site to another each time a process makes a cross processor call; (2) devising a method of updating the system's run queue(s) which prevents two processors from simultaneously changing the same run queue, because this could produce unreliable results; and (3) providing a method for efficiently transferring a process to a another site and, usually, then automatically transferring the process back to its original site.

The present invention solves the primary memory contention and cross processor call problems associated with prior art multiple CPU systems by providing a separate local memory and a separate run queue for each processor. Memory contention is minimized because most processes are run using local memory. When a process needs to be transferred to a specified processor a cross processor routine simply puts the process on the run queue of the specified CPU. The resident memory for the process remains in the local memory for the process's home CPU, and the specified CPU continues execution of the process using the memory in the home CPU. The process is transferred back to its home CPU as soon as the tasks it needed to perform on the specified CPU are completed.

It is therefore a primary object of the present invention to provide an improved multiple CPU computer system.

Another object of the present invention is to provide an efficient system for transferring processes from one CPU to another in a multiple CPU computer system.

SUMMARY OF THE INVENTION

In summary, the present invention is a multiple processor (CPU) computer system, each CPU having a separate, local, random access memory means to which it has direct access. An interprocessor bus couples the CPUs to memories of all the CPUs, so that each CPU can access both its own local memory means and the memory means of the other CPUs. A run queue data structure holds a separate run queue for each of the CPUs.

Whenever a new process is created, one of the CPUs is assigned as its home site and the new process is installed in the local memory means for the home site. When a specified process needs to be transferred from its home site to another CPU, typically for performing a task which cannot be performed on the home site, the system executes a cross processor call, which performs the steps of: (a) placing the specified process on the run queue of the other CPU; (b) continuing the execution of the specified process on the other CPU, using the memory means for the specified process's home site as the resident memory for the process and using the interprocessor bus means to couple the other CPU to the home site memory means, until a predefined set of tasks has been completed; and then (c) placing the specified process on the run queue of the specified process's home site, so that execution of the process will resume on the process's home site.

BRIEF DESCRIPTION OF THE DRAWINGS

Additional objects and features of the invention will be more readily apparent from the following detailed description and appended claims when taken in conjunction with the drawings, in which:

FIG. 1 is a block diagram of a multiprocessor computer system, and some of its most important data structures, in accordance with the present invention.

FIGS. 2A and 2B schematically represent the cross processor call procedure of the preferred embodiment.

FIG. 3 is a block diagram of the CPUSTATE data structure used in the preferred embodiment of the present invention.

FIG. 4 is a flow chart of the process by which a system subroutine call may cause a process to be moved from one site to another in a computer system.

FIG. 5 is a flow chart of the context switching method used in the preferred embodiment of the invention to move a process from one site to another in a computer system.

FIG. 6 is a flow chart of the subroutine SETRQ which is used by the context switching method diagramed in FIG. 4.

FIG. 7 is a flow chart of the method used for creating a new process and assigning it a home site.

FIG. 8 is a block diagram of a virtual memory management page table used in the preferred embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 1, there is shown a block diagram of a multiprocessor computer system 20, and some of its most important data structures, in accordance with the present invention. In a typical configuration, the system 20 includes a main processor MP, and a plurality n of application processors APl to APn.

All of the system's processors are homogeneous, separate one-board microcomputers using a Motorola 68020 central processing unit. For convenience, these processors are also called "CPUs" and "sites".

The system 20 is a multitasking computer system which typically has a multiplicity of processes, also called "user processes" or "tasks", running and waiting to run. As will be described in greater detail below, each user process is assigned a "home site" or "home processor" when it is created.

Cross Processor Calls

The present invention provides a simple system for temporarily moving a user process away from its home site to a specified remote site. To do this, the state of the process is saved (just as it would be saved whenever the process is suspended in any other multitasking system), and then a pointer to the user process is simply added to the remote site's "run queue" and removed from the list of processes running on the home site.

When the remote site picks up this user process from its run queue, it merely reinstates the process and runs the process just like any other process. After the task which required the cross processor call is completed, the interprocessor transfer is reversed by saving the user process's state and adding a pointer to the user process to the run queue for its home site.

The system's memory is organized so that the remote site can use the user process's memory at its home site, rather than moving the process's resident memory to the remote site.

There are several advantages to this approach. The first is that the context which requires a user process to be moved away from its home site need not be copied into a message encapsulating the request, and all references to parameters needed by the process can be made directly to the process's resident memory at the home site. Secondly, there is no need to synchronize one processor with any other. Third, the cross processor call is virtually transparent to the system and requires very little overhead and minimal modification of the system's operating system. In most instances, the only modification to the operating system required is the insertion of a cross processor call in system routines which must be executed on a specified CPU.

In the preferred embodiment cross processor calls are performed only to have a system request serviced which cannot be serviced at the home site of the process. FIGS. 2A and 2B schematically represent the cross processor call procedure of the preferred embodiment.

Referring to FIG. 2A, the process identified as Proc is assumed to have a home site on an applications processor (i.e., not the main processor) and to be running on that home site. The process runs until a system routine is called (box 50). If the system routine can be run locally (box 52), the system routine is simply executed (box 54) and the process continues to run on the home site (box 50).

If, however, the system routine cannot be run locally (box 52), then the process is put on the main processor's run queue (box 56), where it waits until the main processor MP picks it up for execution (box 58). Then the process resumes running on the MP, where it runs the system routine.

After the system routine completes the tasks which need to be performed by the MP, the process is put back on the home site's run queue (box 62), where it waits until the home CPU is ready to pick it up (box 64) and to continue execution of the process (box 50).

Looking at this same process from another perspective, in FIG. 2B at time zero process P1 is running on processor AP and process P3 is running on the main processor MP. At time t1 process P1 performs a system call (i.e., it calls a system routine) which requires processing on the MP. Therefore, shortly after the system call, at time t2, P1's context is saved (in its user structure) and P1 is put on MP's run queue. It should be noted that P1 is usually given a high priority when it performs a cross processor call so that its request will be serviced quickly. Also, when the AP stops running P1 it picks up another process P2 from its run queue and runs that process.

MP continues to run process P3 until some event blocks or interrupts P3's execution at time t3, at which point the MP will run Pl. At time t4, when P1 finishes the system tasks which required the use of the main processor MP, P1's context is saved and it is put back on the run queue for its home site, AP. At this point the MP picks up the highest priority process from its run queue, which may be the process P3 that was interrupted by P1.

AP continues to run process P2 until some event blocks or interrupts P2's execution at time t5, at which point the AP will pick up the highest priority process from its run queue, which may be the process P1.

Memory

Referring again to FIG. 1, each CPU has its own memory module MEM_MP, and MEMl to MEMn, which is used as the primary random access memory for its corresponding CPU.

The resident memory for each user process in the system is located in the memory module for its home site.

While each CPU has its own memory module, these memory modules are multiported and connected to at least one bus so that all physical memory in the system can be accessed by any processor in the system. That is, all of the system's physical memory resides in a single, large physical address space. Also, any given processor can use the page tables describing the virtual memory of any other processor.

As a result of this memory organization, any user process in the system can execute on any of the system's processors, even though the user process's resident memory is located on only one processor (the home site).

Since access to local memory (i.e., access by a CPU to its own memory module) is much faster than cross-processor memory access, the system is designed to run a process as much as possible on its home processor, and to move its execution to another processor only when necessary. Normally, a process's execution is moved away from its home site only to have a system request serviced which cannot be serviced at the home site.

The main processor's memory module MEM_MP holds a number of important data structures including a Process Table 30 which holds essential data regarding each of the processes in the system, a CPUSTATE data structure which contains important data on the status of the processor, and a set of USER data structures which hold data relating to the state of each process allocated to the main processor.

Each processor has a CPUSTATE data structure, which is stored in its local memory. Each processor's local memory also has an array of USER data structures, which are used to hold data relating to the processes allocated to that processor. The details and uses of these data structures are explained below.

Operating System

All of the CPUs use a modified UNIX operating system. (UNIX is a trademark of AT&T Bell Laboratories.) Full UNIX functionality is available in all the processors. To accomplish this, the UNIX kernel has been modified by dividing or replicating portions of the kernel among the MP and attached APs, and adding new interprocessor communication facilities. The interprocessor communication facilities allow requests which cannot be handled locally (e.g., on one of the APs) to be handled by another processor (e.g., the main processor MP).

For those not skilled in the art, it should be known that the term "kernel" is generally used to refer to a set of software routines, including system routines which handle most of the system's hardware dependent functions—such as disk access and other input and output operations. The UNIX kernel is typically copied from disk into the system's random access memory (e.g., the main processor's memory MEM_MP) whenever the system is restarted.

The main difference between the main processor MP and the applications processors AP1 to APn is that the main processor MP is the only processor that can perform certain system functions. For instance, the main processor is the only one which can access the system's disk storage units 22.

The primary goal for the allocation of system functions between the processors is to make the operation of each processor as autonomous as the system's hardware configuration will allow. In other words, each AP is allowed to perform as many system functions locally as is consistent with the system's hardware. This minimizes the frequency of interprocessor function calls and interprocessor memory access.

Interprocessor Busses

Another difference between the main processor MP and the applications processors AP1 to APn is that the main processor has different interprocessor bus connections than the other processors.

The system 20 includes two interprocessor busses 24 and 26. One, called the system composition bus 24, can transfer data between processors at a rate of 12 megabytes per second (12 MB/sec). The other bus, called the interprocessor bus 26, can transfer data between processors at 33.3 MB/sec. The provision of two such busses allows the faster bus to handle video tasks and other task which require high data rates, while the slower bus handles interprocessor memory requests between the main processor and one of the applications processors.

All of the applications processors, AP1 to APn and the system's Display Processor 28 are connected to both busses 24 and 26. The main processor MP is not connected to the faster bus mostly to avoid the cost of adding another high speed port to the main processor, which is already burdened with the disk controller and two terminal ports (not shown in the Figures).

Indivisible Read-Modify-Write Instructions

As will be explained in more detail below, the processors in the system must be able to perform at least one of the "indivisible read-modify-write instructions" known as test and set (TAS), or compare and swap (CAS). Basically, an "indivisible read-modify-write instruction" is an instruction which involves two steps, a test step and then a conditional data writing step, which cannot be interrupted until it is complete.

For instance, the TAS instruction can be used to test if the top bit of a specified memory location is equal to zero, and, if so, to set it equal to one. Making this instruction "indivisible" ensures that while processor AP1 performs a TAS on memory location X, no other processor can modify X. Otherwise, another processor, such as MP or AP2 could modify X after AP1 had tested X's value but before AP1 was able to set X to 1.

An indivisible compare and swap (CAS) instruction works similarly to the TAS instruction, except that the first step compares a first CPU register with a memory location, and the second step stores the value in a second CPU register into the memory location if the comparison's test criterion is satisfied.

In addition to the run queue lock, indivisible read-modify-write instructions are used for updating all data structures that could otherwise be simultaneously accessed and modified by more than one processor. In other words, each such data structure must have a corresponding lock flag and an indivisible read modify write instruction must be used to test the lock flag before the corresponding data structure is updated. Data structures, such as the USER structure, which cannot be simultaneously accessed by more than one processor do not need this lock protection. As will be understood by those skilled in the art, an example of another data structure which requires the use of a lock flag is the sleep queue for each processor.

Process Table

In the main processor's memory module there is a data structure called the process table 30. This table has one row 38 of data for each user process in the system, including the following data which are used in the present invention.

There is a priority parameter 31 which indicates the relative priority of the process. In the preferred embodiment, numerically low priority parameter values are used to indicate high process priority. User processes are assigned priority values between 127 (the lowest priority) and 25 (the highest priority), while system tasks are assigned priority values between 24 and zero.

Each process in the system is either actively running, is waiting to run, or is temporarily inactive. The processes waiting to run on each processor are placed on separate run queues. Similarly, there is a set of sleep queues for temporarily inactive processes, and actively running processes are not on any queue as long as they are running.

Each run queue is simply a linked list formed using the queue link parameter 31 in the process table 30. For each CPU there is a CPUSTATE data structure 40 which points to the row 38 of the process table 30 for the first process in its run queue. The queue link 31 for that process points to the row of the process table for the next process in the processor's run queue, and so on. The entry for the last process in each run queue has a zero in its queue link to indicate that it is at the end of the queue.

For each process, the process table 30 also includes a Home CPU parameter 33 which identifies the assigned home CPU for the process, and a Current CPU parameter 34 which identifies the current CPU on which it is running or waiting to run. The Next CPU parameter 35 is used in cross processor calls to indicate the CPU on which the process is to be run:

Finally, for each process there is a User Struc parameter 36 which points to the User Structure for the process. A separate User Structure, which is a (3072 byte) buffer, is assigned to every process for storing the state of the process, certain special parameters, and for holding a stack called the system mode stack that is used when the process performs certain system mode functions.

While the process table 30 contains other parameters used by the UNIX operating system, only those used for cross processor calls are described herein.

CPUSTATE Data Structure

FIG. 3 is a block diagram of the CPUSTATE data structure used in the preferred embodiment of the present invention. There is one CPUSTATE data structure for each processor in the system.

The CPUSTATE data structure for each processor contains the following parameters. A Run Queue Header 40*a* points to the row of the process table 30 for the first process in the processor's run queue. A somewhat simpler way to state this is to say that the Run Queue Header 40*a* points to the first process in the run queue for the corresponding processor.

The Current Proc parameter 40*b* points to the row of process table 30 for the process currently running in the processor. The Last Proc parameter 40*c* points to the row of process table 30 for the last process which ran in the processor before the current process began running.

The Current Priority parameter 40*d* is the priority value for the process currently running in the processor.

The Run Lock parameter 40*e* is a flag which is normally equal to zero. Any processor which wants to update or modify the processor's run queue is required to check this flag using a TAS instruction before proceeding. If the Run Lock flag is not zero, then some other processor is modifying the run queue and the first processor must wait until it is done. To prevent excessive bus traffic caused by such situations, if a processor finds that a run queue is locked, it is forced to wait a preselected amount of time (e.g., 0.01 milliseconds) before testing the Run Lock again.

If the Run Lock is equal to zero, the run queue is unlocked and the process performing the test sets the Run Lock before proceeding to modify the processor's run queue. When the processor is done with the run queue, it unlocks the run queue by resetting the Run Lock to zero.

The Preemption Flag parameter 40*f* is used to force the processor to look on its run queue for a process of higher priority than the currently running process. Normally, the search for a new process is performed only when the currently running process finishes or reaches a block (such as a cross processor call) which causes it to stopped, at least temporarily. The current process can be preempted, however, if the Preemption Flag 40*f* is given a nonzero value.

Toward the end of the processing of every interrupt which can interrupt a user process, the Preemption Flag 40*f* is checked. If the Preemption Flag is nonzero, a search for a higher priority process than the currently running process is initiated. If a higher priority process is found, the current process is stopped and saved, and the higher priority process is run. In any case, at the end of the preemption search, the Preemption Flag 40*f* is automatically reset to zero.

The set of interrupts which can initiate a preemption search include the interrupt generated by a processor when it puts a high priority process on the run queue of another processor, and a clock interrupt, which occurs 64 times per second.

Next, the CPUSTATE data structure contains a set of Performance Statistics 40*g* which, as described below, are used to help select to a home site for each new process created by the system 20.

The CPUSTATE data structure 40 also contains a list 40*h* of the free pages in its physical memory for use by its virtual memory management system:

Cross Processor Calls

FIG. 4 is a flow chart of the process by which a system subroutine call may cause a process to be moved from one site to another in a computer system. This is essentially a more detailed version of FIG. 2A.

For the purpose of explaining FIGS. 4 through 6, the term "the process" is used to refer to the process which has made a syscall or other subroutine call which has caused a cross processor call to be made.

Whenever a syscall (i.e., a system subroutine call) is made the system first checks to see if the syscall can be run on the current CPU of the process which made the call (box 70). If so, the syscall routine is performed locally (box 86) and, assuming that the process is running on its home CPU (box 88), it returns to the process that performed the syscall (box 90).

If the syscall cannot be performed locally, the following steps are performed. The parameter in the process table called Next CPU is set equal to a pointer to a processor (i.e., to the CPUSTATE data structure for a processor) which can perform the syscall (box 76). Then a variable called Old Priority is set equal to the process's priority (box 78) (which is obtained from the priority entry for the current process in the process table) so that this value can be restored after a context switch is performed.

Next, the process's priority is set to the highest user priority allowed by the system (box 80). This is done so that the process will be serviced as quickly as possible by the main processor.

The context switch itself is performed by calling a routine called SWITCH (box 82), which is described below in detail with reference to FIGS. 5 and 6. The process is now running on the processor pointed to by the Next CPU parameter in the process table 30. In the preferred embodiment, the Next CPU is always the main processor MP, but in other embodiments of this invention the Next CPU could be any processor in the system.

Once the context switch has been made, the process's original priority is restored (box 84) and the syscall routine is performed (86). Then the process is returned to its home cite (boxes 88 to 94). This is done by first checking to see if the current CPU is the process's Home CPU (box 88).

If the Current CPU is the process's Home CPU, no further processing is required and the routine returns (box 90). Otherwise a context switch back to the process's Home CPU is performed by setting the Next CPU parameter equal to the process's Home CPU (box 92), calling SWITCH (box 94), and then returning (box 90).

In the preferred embodiment of the invention, the restoration portion of the syscall handling routine, boxes 88 to 94, is kept simple because (1) there is only one processor to which processes are sent for handling special functions (i.e., the main processor), and (2) none of the syscall routines call other syscall routines. As a result, a process is always returned to its Home CPU after a syscall is complete.

As will be understood by those skilled in the art, in other embodiments of the invention a process might "return" to a CPU other than the process's Home CPU. In such a system a "Return CPU" parameter would have to be added to the system. In such a system, box 88 will be replaced by a query regarding whether "Current CPU=Return CPU?", and if not, the process will be SWITCHed to the Return CPU, which may or may not be the Home CPU.

FIG. 5 is a flow chart of the SWITCH routine used in the preferred embodiment of the invention to move a process from one site to another in a computer system. The first step (box 100) of this routine is to save the context of the current process by storing its registers and such in its USER data structure (see FIG. 1).

Then the run queue for the Current CPU is locked (using the the RUN LOCK 40*e* in the CPUSTATE data structure for the Current CPU) (box 104) and the LAST PROC parameter 40*c* is set equal to CURRENT PROC 40*b*. This reflects the fact that the current process will no longer be running, and hence will be the last process to have run.

Next the CURRENT PROC parameter 40*b* is set equal to a pointer to the process on the run queue with the highest priority, and the CURRENT PRIORITY parameter 40*d* is set equal to this new process's priority (box 108). Then the new CURRENT PROC is removed from the run queue (by modifying the run queue's linked list using standard programming techniques) (box 110) and the Current CPU's run queue is unlocked (box 112) by setting the RUN LOCK parameter 40*e* to zero. Finally, the new current process is started up by restoring the process's context from its USER structure and "resuming" the process (box 114).

Now that the processor which was running the user process has been set up with a new process, the SWITCH program continues by setting up the NEXT CPU to run the user process which is undergoing the context switch. These steps are performed whenever a context switch is done—i.e., only when the NEXT CPU i. not the CURRENT CPU (box 117).

If the process which called SWITCH (now called LAST PROC) is done, or otherwise ready to exit (box 116), and doesn't need any further processing except to be cleaned up and removed from the system, then this clean up is done (box 118) and the SWITCH routine exits (box 122).

Otherwise, if the process (called LAST PROC) is being moved to a new CPU (i.e., its NEXT CPU is not the same as its CURRENT CPUT) (box 117) the SETRQ routine is called (box 120) to move the process identified by LAST PROC to its home site.

If the process which called SWITCH is being suspended (i.e., being put on a sleep queue) or is not switching processors for any other reason (box 117) then the SWITCH routine exits instead of calling SETRQ. Thus the SWITCH is used not only for context switching, but also for activating a new process whenever a CPU's currently running process is suspended.

FIG. 6 is a flow chart of the subroutine SETRQ which is used by the context switching method diagramed in FIG. 5. The SETRQ routine receives as a parameter a pointer to a process which needs to be put onto the run queue of its NEXT CPU, as identified by the entry in the process table 30 (FIG. 1) for that process.

The first step (box 130) of the SETRQ routine is to lock the run queue of the process's NEXT CPU, using an indivisible TAS instruction on the Run LOCK for that CPU. As indicated above, if the Run LOCK for the NEXT CPU is already locked, the system waits for a short period of time and then tries the TAS instruction again, repeating this process until the Run LOCK is unlocked by whatever process was previously using it.

Once the NEXT CPU's run queue is locked, the routine checks to see if the Current CPU is the same as the NEXT CPU (box 132). If so, the process is simply added to the run queue of the current (i.e., NEXT) CPU (box 136) and the run queue for the NEXT CPU is unlocked (box 138) by setting its Run LOCK to zero.

If the current CPU is not the same as the NEXT CPU (box 132) then the Preemption Flag of the NEXT CPU is set and the NEXT CPU is sent a software interrupt (box 134). Then the Current CPU parameter is set equal to NEXT CPU, the process is added to the run queue of the NEXT CPU (box 136) and the NEXT CPU's run queue is unlocked.

The purpose of setting the Preempt Flag and generating an interrupt for the NEXT CPU (box 134) is to force the NEXT CPU to service the process as soon as possible. This combination of steps forces the NEXT CPU to preempt the currently running process with the process added to the run queue, which has been given the highest user priority (see box 108 in FIG. 5). The reason that the interrupt is sent to the NEXT CPU before the process is added to the NEXT CPU's run queue is simply to speed up the process of transferring the process to the NEXT CPU. In effect, the NEXT CPU is forced to begin the process of looking for a new process as soon as possible, but will not actually look through its run queue for the highest priority process therein until its run queue is unlocked several instruction cycles later.

Process Creation and Home Site Selection

Referring to FIG. 7, new processes are created in UNIX systems by a two step process: a fork (box 150) which duplicates an already existing process, and an "exec" step (box 152) which replaces the duplicated process's control program with a program from a specified file.

In systems incorporating the present invention, process creation requires an additional step: selection of a home cite for the new process. In the preferred embodiment, the selection of a home site works as follows.

First (box 154), the process inspects the HOMEMASK parameter for the new process. The HOMEMASK parameter is loaded into the new process's USER structure when the process is created from the paren process at the fork step (box 150). It is a mask that indicates which CPUs the new process can use as a home site. In particular, each bit of the HOMESITE parameter is equal to 1 if the corresponding CPU can be used as a home site, and is equal to 0 if is can't.

The remainder of the home site selection process is restricted to sites allowed by the process's HOMESITE.

Second (box 156), the system calculates the expected memory usage of the new process for each of the processors permitted by its HOMESITE parameter. The process may use less memory in some processors than in others because it may be able to share code already resident at those sites.

Third (box 158), the system picks two candidate sites: (1) the site which would have the most memory left if the process were located there; and (2) the site with the smallest average run queue size which also has enough memory to run the process.

Fourth (boxes 160–164), the system selects as the process's home site, the first candidate if its average queue size is less than the the second candidate's average queue size plus a preselected quantity QZ (a system parameter selected by the person setting up the system, typically equal to 0.5). Otherwise the second candidate site is selected as the home site.

It should be noted that the average queue size for every processor is stored in the Performance Statistics portion 40g of the processor's CPUSTATE data structure, and is updated by the system's clock routine sixty-four times per second.

Also, it can be seen that the selection of a home site is generally weighted in favor of sites with the most memory available.

Finally (boxes 166–168) the new process is moved to its new home site (if it isn't already there), by setting its HOME CPU parameter to the new site, copying its USER structure and resident memory into the memory of the home site, and putting the new process on the home site's run queue by calling SETRQ (not shown as a separate step in FIG. 7).

Memory Management

The UNIX kernel is initially copied from disk into the main processor's random access memory MEM_MP whenever the system is restarted. The other processors initially access the kernel's routines by performing nonlocal memory accesses over the syststem composition bus 24 to MEM_MP.

For purpose of efficient operation, a copy of the portions of the UNIX kernel used by each application processor is copied into local memory. This is done so that each processor can run kernel code without having to perform nonlocal memory access, which is very slow compared to local memory access.

The process by which the kernel code is copied to local memory is as follows.

FIG. 8 is a block diagram of a virtual memory management page table used in the preferred embodiment of the present invention. The use of page tables by the memory management units is well known in the prior art. However, the present invention makes special use of this table.

For each page entry in the MMU page table there is a space for storing a real (i.e., physical) memory address, a "v" flag which indicates if the real memory address is valid (i.e., it indicates whether the page is currently stored in resident memory), a read only RO flag which indicates, if enabled, that the corresponding page cannot be overwritten; a MOD flag, which is enabled if the contents of the page have been modified since the page was first allocated; and a REF flag, which is enable if the contents of the page have been accessed in any way (i.e., either read or written to) since the page was first allocated.

When the system is first started up, the MMU Page Tables in each processor contain entries for all of the UNIX kernel code, with real addresses in the main processor's memory MEM_MP. Every five seconds, a special program in the main processor writes into local memory a copy of all the kernel pages which have been referenced by each applications processor and which have not yet been copied into local memory. References to these pages are thereafter handled by reading local memory rather than the main processor's memory.

While the present invention has been described with reference to a few specific embodiments, the description is illustrative of the invention and is not to be construed as limiting the invention. Various modifications may occur to those skilled in the art without departing from the true spirit and scope of the invention as defined by the appended claims.

For instance, in other embodiments of the present invention, the system's functions could be distributed in such a way that different syscall routines might require cross processor calls to a plurality or multiplicity of different corresponding processors.

Also, in some embodiments of the present invention there could be a dynamic load balancer which would periodically compare the loads on the various processors in the system. The load balancer would be programmed to select candidate processes for being shifted to new home sites, and to transfer a selected process to a new home site if the load on its current home site becomes much heavier than the load on one or more of the other processors in the system.

What is claimed is:

1. A computer system, comprising:

a multiplicity of distinct central processing units (CPUs), each having a separate, local, random access memory means to which said CPU has direct access;

at least one interprocessor bus coupling said CPUs to said multiplicity of memory means, so that each CPU can access both its own local memory means and the memory means of the other CPUs;

run queue means coupled to said CPUs for holding a separate run queue for each of said CPUs; each said run queue holding a list of the processes waiting to run on the corresponding CPU;

process creation means in at least one of said CPUs for creating new processes, for assigning one of said CPUs as the home site of each new process, and for installing said new process in the local memory means for said home site; and

cross processor call means in each of said CPUs, for temporarily transferring a specified process from its home site to another one of said CPUs, for the purpose of performing a task which cannot be performed on said home site, said cross processor call means including means for:

(a) placing said specified process on the run queue of said other CPU;

(b) continuing the execution of said specified process on said other CPU, using the memory means for said specified process's home site as the resident memory for said process and using said interprocessor bus means to couple said other CPU to said home site memory means, until a predefined set of tasks has been completed; and then

(c) upon completion of said predefined set of tasks, automatically returning said specified process to its home site by placing said specified process on the run queue of said specified process's home site, so that execution of the process will resume on said specified process's home site.

2. A computer system as set forth in claim 1, wherein said random access memory means of a first one of said CPUs includes kernel means having a predefined set of software routines for performing predefined kernel functions;

said computer system further including

memory management means coupled to said random access memory means of said CPUs, including

table means for denoting which portions of said kernel means are used by each of said CPUs other than said first CPU; and

kernel copy means, coupled to said table means, for periodically copying into the local random access memory means of each of said other CPUs said kernel portions denoted in said table means as used by said CPU but not previously copied into the local random access memory means of said CPU;

whereby the use of said interprocessor bus for accessing said kernel means is reduced by providing copies, in the local memory means of each CPU, of those portions of said kernel means actually used by each CPU.

3. A computer system as set forth in claim 1, wherein said process creation means includes means for assigning a home site priority to each new process, said home site priority being assigned a value within a predefined range of priority values;

said system further includes process selection means for selecting a process to run on a specified one of said CPUs, when the process currently running in said specified CPU is stopped, by selecting the process in said run queue for said specified CPU with the highest priority; and

said cross processor call means further includes means for

(d) assigning a specified process a higher priority than its home site priority when it is added to the run queue for a CPU other than its home site; and

(e) resetting the priority for said specified process to its home site priority when said process is added to the run queue for its home site;

whereby a process transferred to a CPU other than its home site is given increased priority to accelerate selection of the process for running on said other CPU.

4. A computer system as set forth in claim 3, wherein at least one of said CPUs includes preemption means for finding the highest priority process in its run queue, said preemption means including means for stopping the process currently running said CPU, when said highest priority process has higher priority than the process currently running in said CPU, and then running said highest priority process;

at least one of said CPUs includes interrupt means for activating said preemption means in another one of said CPUs; and

said cross processor call means further includes means for

(f) using said interrupt means in said specified process's home site CPU to activate said preemption means in a specified CPU when said specified process is added to the run queue for said specified CPU;

whereby a process transferred to a CPU other than its home site will be run immediately if its assigned priority is greater than the priorities assigned to the process currently running in said other CPU and to other processes, if any, in said run queue for said other CPU.

5. A computer system, comprising:

a multiplicity of distinct central processing units (CPUs), each having a separate, local, random access memory means to which said CPU has direct access; said CPUs having the capability of executing indivisible read modify write instructions;

at least one interprocessor bus coupling said CPUs to all of said memory means, so that each CPU can access both its own local memory means and the memory means of the other CPUs;

run queue means coupled to said CPUs for holding a separate run queue for each of said CPUs; each said run queue holding a list of the processes waiting to run on the corresponding CPU;

a run lock for each said run queue, said run lock having a first predefined value to indicate that the corresponding run queue is not in the process of being modified by any of said CPUs and is unlocked, and a value other than said first predefined value when the corresponding run queue is being modified by one of said CPUs and is therefore locked;

run queue updating means coupled to said CPUs for adding or removing a specified process from a specified run queue, said run queue updating means including means for:

(a) locking said specified run queue by

(a.1) using an indivisible read modify write instruction to test the value of the run lock for said specified run queue and, if said run lock value indicates that said specified run queue is unlocked, to set said run lock to a value which indicates that said specified run queue is locked; and

(a,2) if the test in step (a,1) determines that said run queue is locked, performing step (a,1) again after a predefined delay, until the test in step (a1) determines that said run queue is unlocked;

(b) adding or removing a specified process from said specified run queue; and

(c) unlocking said specified run queue by setting said run lock for said specified run queue to said first predefined value;

process creation means in at least one of said CPUs for creating new processes, for assigning one of said CPUs as the home site of each new process, and for installing said new process in the local memory means for said home site; and

cross processor call means in each of said CPUs for temporarily transferring a specified process from its home site to a specified one of said other CPUs, for the purpose of performing a task which cannot be performed on said home site, said cross processor call means including means for:

(a) using said run queue updating means to add said specified process to the run queue of said specified CPU;

(b) continuing the execution of said specified process on said specified CPU, using the memory means for said specified process's home site as the resident memory for said process and using said interprocessor bus means to couple said specified CPU to said home site memory means, until a predefined set of tasks has been completed; and then

(c) upon completion of said predefined set of tasks, automatically returning said specified process to its home site by using said run queue updating means to add said specified process to the run queue of said specified process's home site, so that execution of the process will resume on said specified process's home site.

6. A computer system as set forth in claim 5, wherein said process creation means includes means for assigning a home site priority to each new process, said home site priority being assigned a value within a predefined range of priority values;

said system further includes process selection means for selecting a process to run on a specified one of said CPUs, when the process currently running in said specified CPU is stopped, by selecting the process in said run queue for said specified CPU with the highest priority; and

said cross processor call means further includes means for

(d) assigning a specified process a higher priority than its home site priority when it is added to the run queue for a CPU other than its home site; and

(e) resetting the priority for said specified process to its home site priority when said process is added to the run queue for its home site;

whereby a process transferred to a CPU other than its home site is given increased priority to accelerate selection of the process for running on said other CPU.

7. A computer system as set forth in claim 6, wherein at least one of said CPUs includes preemption means for finding the highest priority process in its run queue, said preemption means including means for stopping the process currently running said CPU, when said highest priority process has higher priority than the process currently running in said CPU, and then running said highest priority process;

at least one of said CPUs includes interrupt means for activating said preemption means in another one of said CPUs; and

said cross processor call means further includes means for

(f) using said interrupt means in said specified process's home site CPU to activate said preemption means in a specified CPU when said specified process is added to the run queue for said specified CPU;

whereby a process transferred to a CPU other than its home site will be run immediately if its assigned priority is greater than the priorities assigned to the process currently running in said other CPU and to other processes, if any, in said run queue for said other CPU.

8. A computer system, comprising:

a multiplicity of distinct central processing units (CPUs), each having a separate, local, random access memory means to which said CPU has direct access; said CPUs having the capability of executing indivisible read modify write instructions;

at least one interprocessor bus coupling said CPUs to all of said memory means, so that each CPU can access both its own local memory means and the memory means of the other CPUs;

process creation means coupled to said CPUs for creating new processes, for assigning one of said CPUs as the home site of each new process, for installing said new process in the local memory means for said home site, and for assigning a home site priority to each new process, said home site priority being assigned a value within a predefined range of priority values;

run queue means coupled to said CPUs for holding a separate run queue for each of said CPUs; each said run queue holding a list of the processes waiting to run on the corresponding CPU;

process table means coupled to said CPUs for retaining information regarding every process running or otherwise in existence in said system, including for each said process

a HOME CPU parameter which indicates the home site of said process;

a CURRENT CPU parameter which indicates the current CPU on which said process is running, waiting to run, or otherwise residing; and

a PRIORITY parameter indicative of the priority of said process;

cpustate table means for storing information regarding each said CPU, including:

a run queue header identifying the run queue for said CPU;

a current process parameter identifying the process currently running in said CPU;

a last process parameter identifying the process which was run prior to the process currently running in said CPU; and

a run lock parameter which is given a first predefined value to indicate that the corresponding run queue is not in the process of being modified by any of said CPUs and is unlocked, and a value other than said first predefined value when the corresponding run queue is being modified by one of said CPUs and is therefore locked; and

run queue updating means coupled to said CPUs for adding or removing a specified process from a specified run queue, said run queue updating means including means for:

(a) locking said specified run queue by

(a,1) using said indivisible read modify write instruction to test the value of the run lock for said specified run queue and, if said run lock value indicates that said specified run queue is unlocked, to set said run lock to a value which indicates that said specified run queue is locked; and

(a,2) if the test in step (a,1) determines that said run queue is locked, performing step (a,1) again after a predefined delay, until the test in step (a1) determines that said run queue is unlocked;

(b) adding or removing a specified process from said specified run queue;

(c) unlocking said specified run queue by setting said run lock for said specified run queue to said first predefined value; and

(d) updating said run queue header, current process and last process parameters of the cpustate table means for the CPU corresponding to said specified run queue to reflect the current status of said CPU;

process selection means in at least one of said CPUs for selecting a process to run on a specified one of said CPUs when the process currently running in said specified CPU is stopped, including means for selecting the process in said run queue for said specified CPU with the highest priority and means for initiating the running of said selected process in said specified CPU; and

preemption means in each CPU for finding the highest priority process in its run queue, said preemption means including means for stopping the process currently running in said CPU, when said highest priority process has higher priority than the process currently running in said CPU, and then running said highest priority process;

interrupt means in each said CPU for activating said preemption means in a specified one of the other CPUs; and

cross processor call means in each of said CPUs for temporarily transferring a specified process from its home site to a specified one of said other CPUs, for the purpose of performing a task which cannot be performed on said home site, said cross processor call means including means for:

(a) using said run queue updating means to add said specified process to the run queue of said specified CPU;

(b) assigning said specified process a higher priority than its home site priority when it is added to said run queue for said specified other CPU;

(c) using said interrupt means in said specified process's home site CPU to activate said preemption means in said specified CPU when said specified process is added to said run queue for said specified CPU, so that said specified process will be preempt the process currently running in said specified CPU;

(d) continuing the execution of said specified process on said specified CPU, using the memory means for said specified process's home site as the resident memory for said process and using said interprocessor bus means to couple said specified CPU to said home site memory means, until a predefined set of tasks has been completed; and then

(e) upon completion of said predefined set of tasks, automatically returning said specified process to its home site by using said run queue updating means to add said specified process to the run queue of said specified process's home site, so that execution of the process will resume on said specified process's home site; and

(f) resetting the priority for said specified process to its home site priority when said process is added to said run queue for its home site.

9. A method of running a multiplicity of processes in a computer system, comprising the steps of:

providing a computer system having

(1) a multiplicity of distinct central processing units (CPUs), each having a separate, local, random access memory means to which said CPU has direct access; said CPUs having the capability of executing indivisible read modify write instructions; and

(2) at least one interprocessor bus coupling said CPUs to all of said memory means, so that each CPU can access both its own local memory means and the memory means of the other CPUs;

wherein at least one of said CPUs is capable of performing one or more tasks that at least one of said other CPUs cannot perform;

generating a run queue data structure for holding a separate run queue for each of said CPUs; each said run queue holding a list of the processes waiting to run on the corresponding CPU;

providing run queue updating means for adding or removing a specified process from a specified run queue;

creating new processes, as the need arises, including the step of assigning one of said CPUs as the home site of each new process, and installing said new process in the local memory means for said home site; and

when one of said processes needs to perform a task which cannot be performed on its home site, performing a cross processor call to temporarily transfer said process from its home site to a specified one of said other CPUs which is able to perform said task, be performing the steps of:

(a) using said run queue updating means to add said process to the run queue of said specified CPU;

(b) continuing the execution of said process on said specified CPU, using the memory means for said process's home site as the resident memory for said process and using said interprocessor bus means to couple said specified CPU to said home site memory means, until a predefined set of tasks has been completed; and then

(c) upon completion of said predefined set of tasks, automatically returning said specified process to its home site by using said run queue updating means to add said process to the run queue of said process's home site, so that execution of the process will resume on said process's home site.

10. A method as set forth in claim 9, further including the step of generating a run lock flag for each said run queue, said run lock having a first predefined value to indicate that the corresponding run queue is not in the process of being modified by any of said CPUs and is unlocked, and a value other than said first predefined value when the corresponding run queue is being modified by one of said CPUs and is therefore locked;

wherein said step of providing run queue updating means includes providing run queue updating means for adding or removing a specified process from a specified run queue by performing the steps of:

(a) locking said specified run queue by

(a,1) using said indivisible read modify write instruction to test the value of the run lock for said specified run queue and, if said run lock value indicates that said specified run queue is unlocked, to set said run lock to a value which indicates that said specified run queue is locked; and

(a,2) if the test in step (a,1) determines that said run queue is locked, performing step (a,1) again after a predefined delay, until the test in step (a1) determines that said run queue is unlocked;

(b) adding or removing a specified process from said specified run queue; and

(c) unlocking said specified run queue by setting said run lock for said specified run queue to said first predefined value.

11. A method as set forth in claim 9, wherein said step of creating new processes includes assigning a home site priority to each new process, said home site priority being assigned a value within a predefined range of priority values;

said method further including the step of selecting a process to run on a specified one of said CPUs, when the process currently running in said specified CPU is stopped, by selecting the process in said run queue for said specified CPU with the highest priority; and

said step of performing a cross processor call further includes the steps of

(d) assigning a specified process a higher priority than its home site priority when it is added to the run queue for a CPU other than its home site; and

(e) resetting the priority for said specified process to its home site priority when said process is added to the run queue for its home site;

whereby a process transferred to a CPU other than its home site is given increased priority to accelerate selectic.n of the process for running on said other CPU.

12. A method as set forth in claim 11, wherein said step of performing a cross processor call further includes the step of

(f) generating a preemption interrupt in said specified CPU when said specified process is added to the run queue for said specified CPU;

said method further including the step of responding to a preemption interrupt in a specified CPU by:

(a) finding the highest priority process in the run queue of said specified CPU; and

(b) stopping the process currently running in said CPU, when said highest priority process has higher priority than the process currently running in said CPU, and then running said highest priority process;

whereby a process transferred to a CPU other than its home site will be run immediately if its assigned priority is greater than the priorities assigned to the process currently running in said other CPU and to other processes, if any, in said run queue for said other CPU.

13. A method as set forth in claim 9, further including the steps of:

providing a predefined set of kernel routines in said local memory means of a first one of said CPUs;

denoting, in a predefined data structure, which of said kernel routines are used by each of said CPUs other than said first CPU; and

periodically copying into the local random access memory means of each of said other CPUs said kernel routines denoted in said predefined data structure as used by said CPU but not previously copied into the local random access memory means of said CPU;

whereby the use of said interprocessor bus for accessing said kernel routines is reduced by providing copies, in the local memory means of each CPU, of those kernel routines actually used by each CPU.

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